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When the program calling for unprecedented quantities of planes, tanks, ships, trucks, etc., was outlined, it was evident that the oil to operate these vehicles of war would be just as essential as the vehicles themselves. Inasmuch as we were wholly engaged in the manufacture of indispensable tools for the oil producing industry, we were already an important cog in this emergency program.

The task before us, therefore, was to continue furnishing these tools and to devote whatever additional capacity we had or could develop to other vital war production.

Military regulations prohibit publication of complete information on war production, but this we can say:

We are operating four plants. Two are of company ownership, two of government ownership.

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Our California plant (operated under the name of Hughes Aircraft Co.) is also completely devoted to war work, the major item now being the design and construction of large cargo planes.

Like other branches of industry, we have had our problems over machine tools, materials, technical procedures, and skilled labor. As we have solved these problems in the past, we expect to solve new ones as they arise.

We pledge our facilities and our manufacturing skill to the fulfillment of the emergency program—and we hope that our broader experience will enable us to render the Petroleum Industry still greater service after the Victory is won.

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EDITORIAL

DUPLICATION AND DIVISION HAMPER WAR EFFICIENCY

INEPT and fumbling treatment of the fundamentally important oil price question directs renewed attention to the most serious defect in the administrative machinery set up by the government for directing industrial activities essential to successful conduct of the war. This is the division of authority and the duplication of activities among federal agencies—in this case the insistence of the Office of Price Administration on duplicating work belonging within the field of the Petroleum Administration and much more effectively performed by that body. There is no question of the need for governmental supervision of war production. There is no denial of the importance of extending some measure of control over prices and keeping them in proper correlation. But all this could be accomplished much more soundly and effectively with a clear-cut definition of the function of each official organization and of the limitations within which each is expected to operate.

The fundamental importance of oil in the prosecution of the war was recognized at the beginning of the national emergency by the establishment of the Office of Petroleum Administration with a nation-wide organization. That organization has drawn to itself men of high ability and broad experience in all branches of oil administration. Under the able direction of Secretary Ickes it has come to be recognized as one of the most efficient of federal agencies. Its function is to provide the tremendous supplies of petroleum products required by the war itself and by the activities in the field of production needed to sustain the armies and navies of the United Nations. In pursuance of its duties it makes specific and detailed studies of physical operations, financial results, material requirements and all other matters pertaining to the ability of the industry to meet wartime needs without impairing its ability to serve subsequent peace-time demands. It is the one official group best qualified to measure the present and future necessities of the industry.

In one all-important factor influencing the effectiveness of oil industry operations, however, authority rests not with the Petroleum Administration but with the Office of Price Administration which determines the price at which oil and oil products may be sold. While a good case may be made for a special bureau to pass upon price adjustments and their effect upon the price control program to which the federal administration is theoretically committed it would be logical for the Price Administrator to accept the factual findings of the Petroleum Administration which is much more closely in touch with the entire petroleum picture than he can possibly be and to give great weight to such recommendations as the Petroleum Administrator may make.

Actually however the Office of Price Administration maintains its own Fuel Price Division, makes its own investigations, apparently in complete disregard of the carefully prepared studies of the Petroleum Administration, and arrives at its decisions on the basis of conclusions entirely removed from their effect upon the ability of the petroleum industry to discharge its mounting responsibilities toward the successful prosecution of the war. Its course nullifies the team work to be expected from governmental agencies established for the purpose of adding to the strength of the nation in crushing Axis aggression.

It cannot be asserted that the Petroleum Administration has failed to recognize in every particular the authority and position of the Office of Price Administration. Representatives of OPA are invited to pre-audit the PAW fact-finding procedures and are urged to specify the particular information that must be presented in order to satisfy OPA that a specific price adjustment proposal is essential to continued production on the scale demanded by the requirements of war. When the facts are thus presented and made the basis of well considered recommendations by the body primarily responsible for the satisfaction of these requirements there is no reason why costly and dangerous delays should result because of an unnecessary and intolerable duplication of effort in investigation and examination. In the treatment of the oil price question which has been before the Price Administration in one form or another for a year and a half the course of that agency has been marked by a disposition to delay serious consideration of the fundamental issue, to divert attention to minor and unessential considerations and to advance impractical and half-baked suggestions for dealing with a problem that reason and experience show can be met successfully in one simple and straightforward way. That this attitude results from a failure to grasp the fundamental importance of an adequate and unfailing oil supply to the successful conduct of the war or the gravity of the danger involved in continuing neglect of action to maintain that supply points clearly to the necessity for a greater centralization of authority or a more genuine coordination of effort.

OIL PRICE A QUESTION OF WAR NECESSITY

PRICE Administrator Brown's rejection of the recommendation for a rise in the price of crude oil submitted by the Petroleum Administrator for War has done nothing to settle that question. On the contrary it has stirred up widespread criticism, renewed protests and acrimonious comment in many quarters outside the immediate membership of the oil industry. Only by the strenuous efforts of administration leaders in Congress have members of that body been restrained from proceeding with legislative action to force a price readjustment. Officials of oil producing states have visited Washington to present personally the gravity of the situation confronting the country in the matter of its future oil supply. Secretary Ickes in his capacity of Petroleum Administrator has in effect repudiated the findings by requesting a reconsideration of his recommendation. These are not the protests of individuals who stand to profit by a revision of existing price ceilings. They are motivated by genuine alarm at the results of persistence in maintaining oil prices at a level far below that of other essential commodities.

In the oil industry itself the conviction prevails that the application was not decided upon its merits but that the finding of the Price Administrator was predetermined by considerations having nothing to do with the factual data presented. Disappointment is particularly keen among the small producers who have found it difficult or impossible to meet rising costs of operation at the artificially low levels arbitrarily imposed upon their products. They have been encouraged to hold on and to avoid the sacrifice or abandonment of their wells in the hope that the difficulties of their position would be recognized and removed. They have watched with such patience as they could muster the slow progress of the move toward recognition of the situation through the Petroleum Industry War Council and through its protracted consideration by the Petroleum Administration, only to see the application for more equitable prices summarily rejected by the Price Administrator.

Disappointment at the decision itself has been heightened by the statement in which the Price Administrator sought to justify his action. In this pronouncement it is stated that exploratory drilling is going on at a rate "approximately the same as last year . . . although this rate does not measure up to the goal of 4,500 wildcat wells for 1943 which your (Petroleum Administrator's) office has established." The proposal for wildcat drilling was set at the lowest figure which the qualified experts of the Petroleum Administrator's staff felt might uncover fresh reserves approximating necessary withdrawals during the year. It was a minimum figure admittedly inadequate to establish a desirable backlog of known available supplies and the fact that it is not being approached in actual drilling cannot be dismissed as inconsequential. In reality statistics for the first quarter of the year show that drilling has been below the 1942 rate in every part of the country except California where a small increase in the price of certain grades of crude has been granted. The figures certainly do not support the statement that drilling is approximately at the same rate as during the corresponding period of last year.

Similarly the abandonment of stripper wells is minimized by the statement that only 3⅓ per cent of the total number were abandoned during 1942 and the suggestion that a plan of keeping in operation such wells as are worth saving can be devised at much less cost than would be involved in a general price increase, but no intimation as to how this is to be accomplished is given. The inability to expand production by secondary recovery projects is dismissed with the remark that "it has been our policy for some time to make such necessary price adjustments in cases where the crude oil producer is able and willing to absorb the increase. It is my thought that situations where the purchaser cannot absorb an increase in crude prices can be handled by an obvious variation of the oil-payment plan." Exactly what this means is left for the practical oil man to determine if he can.

Most disturbing of all in its revelation of incapacity to deal effectively with the problem of falling reserves is the Price Administrator's revival of the discredited proposal of a government subsidy for exploratory drilling. Subsidies have been the favorite recourse of the present administration for dealing with economic maladjustments arising from attempts to interfere with the normal working of the law of supply and demand. They have been employed to raise the price of farm products and for other purposes but in no instance with results satisfactory to the recipients or the public. In no other field of industry, it is safe to say, is this type of financial support less likely to prove effective than in wildcat drilling. The entire history of the search for petroleum shows that it calls for the pioneering spirit, the willingness to assume great risks and persistence in the face of discouraging circumstances that are attributes of private enterprise. In no part of the world has government directed exploration produced results comparable to those obtained by individual and company effort. The conditions under which governments must operate simply do not lend themselves to this type of undertaking. Protection against loss in random drilling is no sufficient substitute for the profit incentive which has built up the American oil industry to its present preeminent position.

As has been pointed out in these pages many times oil is an imperative essential to the successful prosecution of the war. It should be treated as other war needs have been, by doing whatever is necessary to assure complete sufficiency. While the precise amount of petroleum products demanded by the offensives conducted by the United Nations on many battle fronts is cloaked in military secrecy the public has been warned in many official statements that it has reached staggering proportions and that it will continue to rise until the struggle reaches its end. Under these conditions this country cannot disregard the necessity of maintaining ample reserves through more intensive exploration nor can it afford to sacrifice any part of the recoverable resources which it now possesses. This is the consideration that moved the Petroleum Administrator to make his original recommendation and which has led him to reopen the subject. It is the issue on which the question must finally be settled.

"I am one of those who believe that foreign capital should be attracted to the country, and that once in it, its investment should be guaranteed so as to provide reasonable benefits for both the nation and the investor . . . the law is in fact a just and equitable one whereby the peaceful development of the companies' industrial and commercial activities will be protected by the institutions of a Republic of free men who know how to keep their word. It is fitting to acknowledge here the goodwill which the companies who have agreed to subject themselves to the new law have shown in the course of negotiations, and speaking with the moral authority given me by my position and the fact that I initiated this revision, I should like to tell the Venezuelan public that these companies have shown themselves worthy of our appreciation and esteem."

VENEZUELA'S NEW PETROLEUM LAW

By Ruth Sheldon

Caracas, Venezuela

AN important chapter of oil history was written in Venezuela March 13 when a new petroleum law was enacted which amicably terminated a long controversy between the government and the oil companies operating in the country. In its completed form the law is regarded here as a model example of how government and private enterprise can work together for their mutual benefit.

The new law has managed to strike a balance whereby the Venezuelan government will receive the utmost that is economically practicable from the development of its petroleum resources while at the same time permitting their continued development by private capital on a stable basis.

The adjustment is looked upon as an example of workable Pan-Americanism and as laying the groundwork for a realistic approach to the oil problem in the other countries of the Western Hemisphere.

How this has been accomplished, the difficulties surmounted and the specific results obtained makes an interesting and significant chronicle of the time.

Unsettlement of Venezuela's oil situation began in 1935 upon the death of dictator General Juan Vicente Gomez who had ruled the country for 26 years. During his regime the oil industry had undergone a great development under the liberal treatment accorded to foreign capital and petroleum had become the country's most important business, providing directly and indirectly two-thirds of the national income. While most of the Venezuelan oil consessions were held by a small number of companies there was no uniformity in the matter of terms. Concessions had been granted at different times, for different periods and called for varying rates of payment to the government. Royalty rates ranged from 7½ to 15 percent and in the case of certain concessionaires no percentage royalty was paid but instead a flat royalty tax of two bolivares per ton produced, about nine cents per barrel in U. S. currency. Through tariff exoneration the companies were permitted to bring into the country duty-free the machinery and supplies needed for their operation. In government circles it was felt that a new petroleum law was needed partly to establish uniform regulations but primarily to give the federal treasury a larger revenue from oil.

Consequently, in 1936 a new law was passed applying to all new concessions. Royalties and taxes were increased and exoneration of duties could be granted only on imports of equipment not manufactured in Venezuela. This new law was no solution to the fundamental problem, for it applied only to new concessions while the old ones continued to operate on the basis previously applying.

Still dissatisfied with its participation, the government passed another law in 1938. Royalties and taxes were further increased. There was no exoneration of duties except at the discretion of the government. But the most stringent feature of the law was a provision that if in the opinion of the federal executive exploitation was not carried on with reasonable intensity the operator must exploit the concession as the government decreed or else forfeit it to the government with no indemnification. The oil companies felt this left the door wide open for expropriation at any time the government might desire it and although the companies were eager to extend their concessions they were unwilling to take them out under this law.

With the coming of war and the interruption of transportation which made it necessary to cut down the output of the Venezuelan wells the concern of the government over the falling off in its oil revenues was greatly increased and the demand for some action to improve its income from this source became more insistent.

When President Isaias Medina A. was inaugurated, May 5, 1941, it was made known that he intended to establish a new basis of relationship between the government and the oil companies. Two months after his inaguration he sent Dr. Gustavo Manrique Pacanins, the Attorney-General of Venezuela, to New York to discuss with the oil companies a revision of the oil law which would satisfy the government's requirements. Dr. Manrique knew the problems involved more intimately than any other official

of the government and was fully advised of the demands which the administration proposed to insist upon. At his suggestion discussions were held in Caracas for several months but without leading to an agreement. Meanwhile the spread of Axis submarine operations across the Atlantic and the entry of the United States into the war interjected a new element. Tanker sinkings in the Caribbean rose alarmingly. Venezuela's oil production was cut back by 35 percent. The decrease in the country's oil revenue was felt more sharply. At the same time, Venezuela found it impossible to import needed commodities. The cost of living rose rapidly, unemployment spread and public discontent increased.

President Medina, being an army man by training, decided upon more drastic action. In July, 1942, he announced his intention of revising the national oil policy so that Venezuela would enjoy a larger participation in the exploitation of its oil resources. Again he sent the Attorney-General to the United States but this time to Washington with a special message to President Roosevelt advising the latter of his intention to revise the law regardless of the objections of the oil companies. The Venezuelan government felt that the oil companies had continuously opposed the government through "passive resistance" and that this could not be permitted to continue.

When the facts were placed before the Department of State, the situation took a new turn. Max Thornburg, Petroleum Adviser to the State Department, conferred informally with the oil companies and suggested that it would be wise for them to reopen negotiations with the Venezuelan government on a new and completely co-operative basis. He suggested that they submit their ideas as to what would be an equitable operating basis for the Venezuelan industry so that a definite program could be formulated. The oil companies agreed to do this.

In the meantime, Dr. Manrique had arranged to retain a firm of American engineers, Herbert Hoover, Jr., and A. A. Curtice, to come to Caracas to advise the Venezuelan government in its negotiations with the oil companies so that the government would be completely and technically informed on all points to be discussed. Hoover and Curtice had had wide experience in South America serving various governments; they were not connected with any oil company and they were in a position to advise the government impartially. This move on the part of the Venezuelan government was accepted by the oil companies as an evidence of the government's intention and desire to work out a sound technical basis for operations.

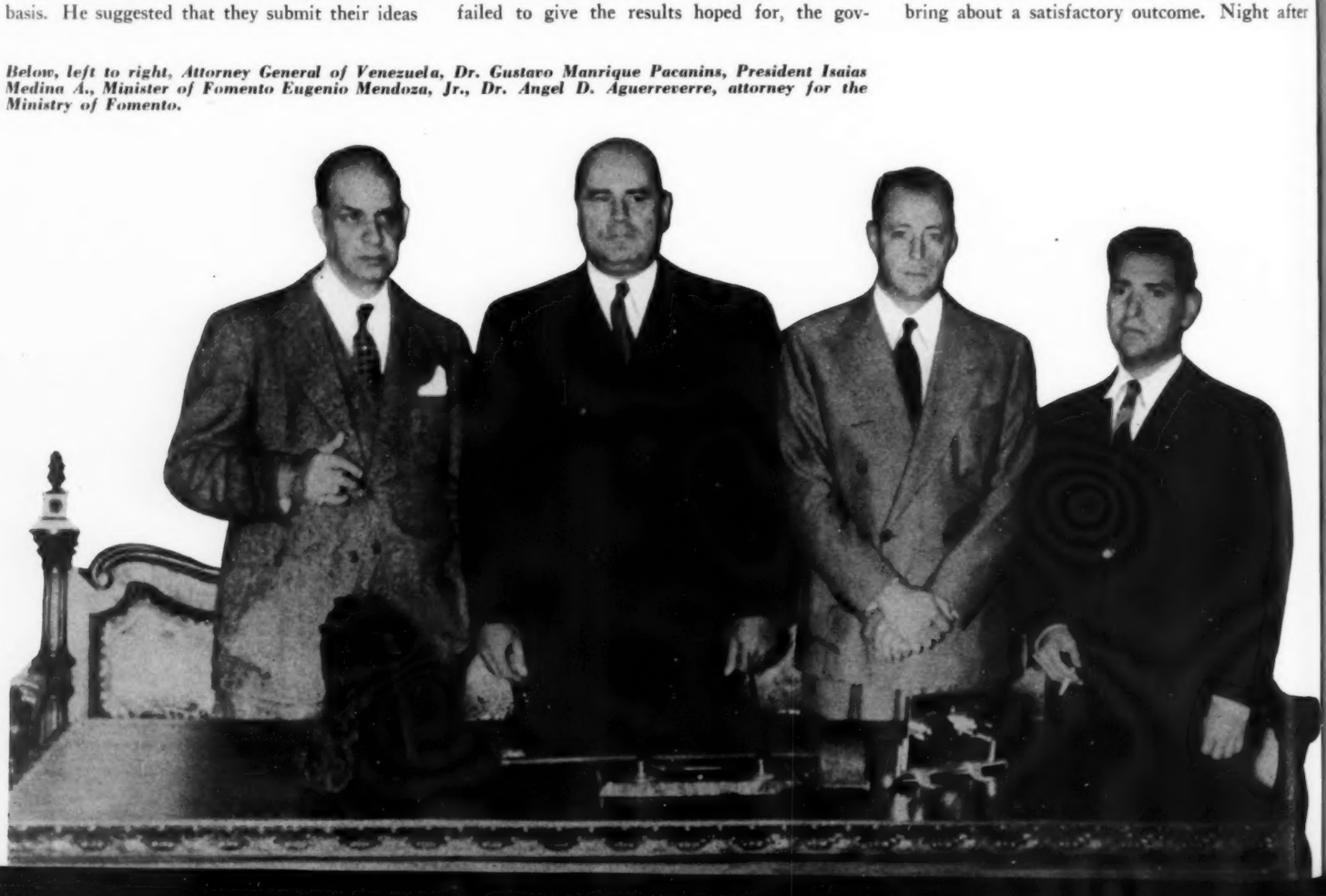
The oil companies arranged to send special representatives to Caracas. Hoover and Curtice arrived, and negotiations began under the direction of Minister of Fomento Mendoza. President Medina made an address to the Venezuelan nation at Maracaibo, in which he said that the government was in duty bound to obtain more revenue from the oil industry, that Venezuelan oil should be refined chiefly in Venezuela and that while the government intended to respect legitimately acquired rights and did not regard the oil companies as enemies, nevertheless he felt that contracts are lasting only when they are based on justice and equity. He added that when he announced his oil policy he was sure that revision would be obtained either through mutual agreement or through legal steps, but, he continued, if the first of these measures failed to give the results hoped for, the government would use every legal and moral means to obtain what the nation was entitled to. The year 1942, he concluded, would mark the end of an era in the history of the Venezuelan oil industry: the era of trial, experiment and ignorance. He proposed a new era of technical exploitation at the service of the state in cooperation with private enterprises on a partnership basis.

Due to the friendly attitude of the American State Department and the informal work which Petroleum Adviser Thornburg had done in paving the way so that negotiations could be reopened, President Medina invited Mr. Thornburg to come to Venezuela as his personal guest to see how the negotiations were progressing and to discuss general problems.

The President's prediction proved correct. By December all the major differences between the companies and the government had been ironed out and a draft of a new law had been prepared. The beginning of the new era was in sight.

In January, the President appointed a special commission of cabinet members, attorneys and engineers to study the first draft of the law which had been informally worked out. For a month this commission, working with Hoover and Curtice, studied the suggestions, clarified them and submitted them to the oil companies for criticism and recommendations. Minister of Fomento, Eugenio Mendozo, Jr., under whose department all oil matters are handled, had working for him a group of young Venezuelan engineers and the government was acting upon their advice in conjunction with that of the American engineers retained by the government. Throughout this difficult time President Medina labored as zealously as any of the negotiators to bring about a satisfactory outcome. Night after

Below, left to right, Attorney General of Venezuela, Dr. Gustavo Manrique Pacanins, President Isaias Medina A., Minister of Fomento Eugenio Mendoza, Jr., Dr. Angel D. Aguerreverre, attorney for the Ministry of Fomento.



night he would stay in the Palace of Miraflores "working like a clerk," as one cabinet minister expressed it, making decisions on the problems that were presented to him, mediating differences and passing upon proposals submitted for incorporation in the law.

Although the government and the companies had reached a working agreement upon the majority of questions there were two problems which had to be clarified before the new law could be sent to Congress. One was the question of refining within the country and the other was the disposal of a number of pending suits by the government against the companies which principally involved exoneration from duties.

The refining question was the more difficult. Venezuela always has been resentful of the fact that two of the largest refineries in the world are located on two Dutch islands, Aruba and Curacao, a few miles off her northern coast and that these refineries, one owned by the Standard and the other by Shell, handle the majority of Venezuelan crude. Geographically these islands are a part of Venezuela and industrially they are a part of Venezuela's oil picture. The fact that Venezuela receives no revenue from the refining of its oil only a few miles away and that the 9,800 workers in the refineries are not Venezuelans has been something to which the nation has never been reconciled.

When the refineries were originally built, according to the oil companies, the Dutch West Indies were selected as a location because they possessed harbor facilities for ocean-going tankers, while the Venezuelan fields centered mainly about Lake Maracaibo where only shallow draught vessels could be employed.

This refining grievance was so fixed in the minds of the Venezuelan public that something had to be done. President Medina had promised the people it would be solved. The companies pointed out that the refineries could not be moved from Curacao and Aruba to Venezuela as the cost would be prohibitive. To move them would cost at least 80 percent of the cost of new refineries of equivalent capacity, a sum of at least $125,000,000. And if the cost of loss of production while the refineries were being moved was added, the overall cost would exceed $200,000,000.

President Medina was insistent that the oil companies commit themselves to a definite refining policy in agreement with the Venezuelan government. It was finally worked out that the Jersey Company and Shell would locate in Venezuela itself any additional refinery capacity needed to handle Venezuelan crude. The Jersey Company also agreed to build 40,000 barrels refining capacity in Venezuela within five years after the war ends or whenever materials are available. Shell agreed to do likewise.

Three newcomers to the scene—Socony, Texas and Sinclair—also have refining agreements with the government. These refineries will be built whenever the companies obtain the production to justify it. At present the Sinclair company is the only one with sufficient production, having developed within the past two years better than 41,000 barrels daily production and having completed a 12-inch pipeline of 70,000 barrels daily capacity from its fields in Eastern Venezuela to the coast at Puerto la Cruz, where it has a modern loading terminal. The Sinclair company proposes to construct as soon as possible a modern refinery to produce everything from aviation gasoline to toluene. All this will lay the basis for a real refining industry in Venezuela and will alleviate the feeling that has developed over this subject.

The question of exoneration suits was quickly settled. The government had claims against the companies amounting to approximately $10,000,000. Some of these claims were for other matters, but the majority were disputes over the duties the companies felt they should not be forced to pay on material brought into the country. Minister of Fomento Mendoza suggested a compromise whereby the companies would pay half the amount the government claimed and the suits would be dismissed. This the companies agreed to.

With these two questions out of the way, the draft of the new law was ready to present to Congress. President Medina convened a special session February 23, and announced that the new law was a just and final solution to Venezuela's oil problem for it did not represent merely another petroleum law which would apply to concessions granted in the future, but it contained provision for the companies to voluntarily convert all their existing concessions to the new regulations. So carefully and satisfactory had the law been worked out that the companies had agreed to convert all their concessions to it. This would mean that for the first time all Venezuelan oil would be governed by a single law and one that was technically and economically sound, not only in regard to existing conditions but flexible enough to take care of the future development of the industry.

The new law was passed both by the Chamber of Deputies and the Senate in record time with only a few minor changes and was presented to President Medina for his signature March 13.

The new law is based in large part on the 1936 oil law but with important changes.

A uniform royalty is established whereby Venezuela will receive 16⅔ percent of all oil produced. Formerly, the government received an average of approximately nine percent. The goverment is privileged to take this royalty oil either in cash or in kind.

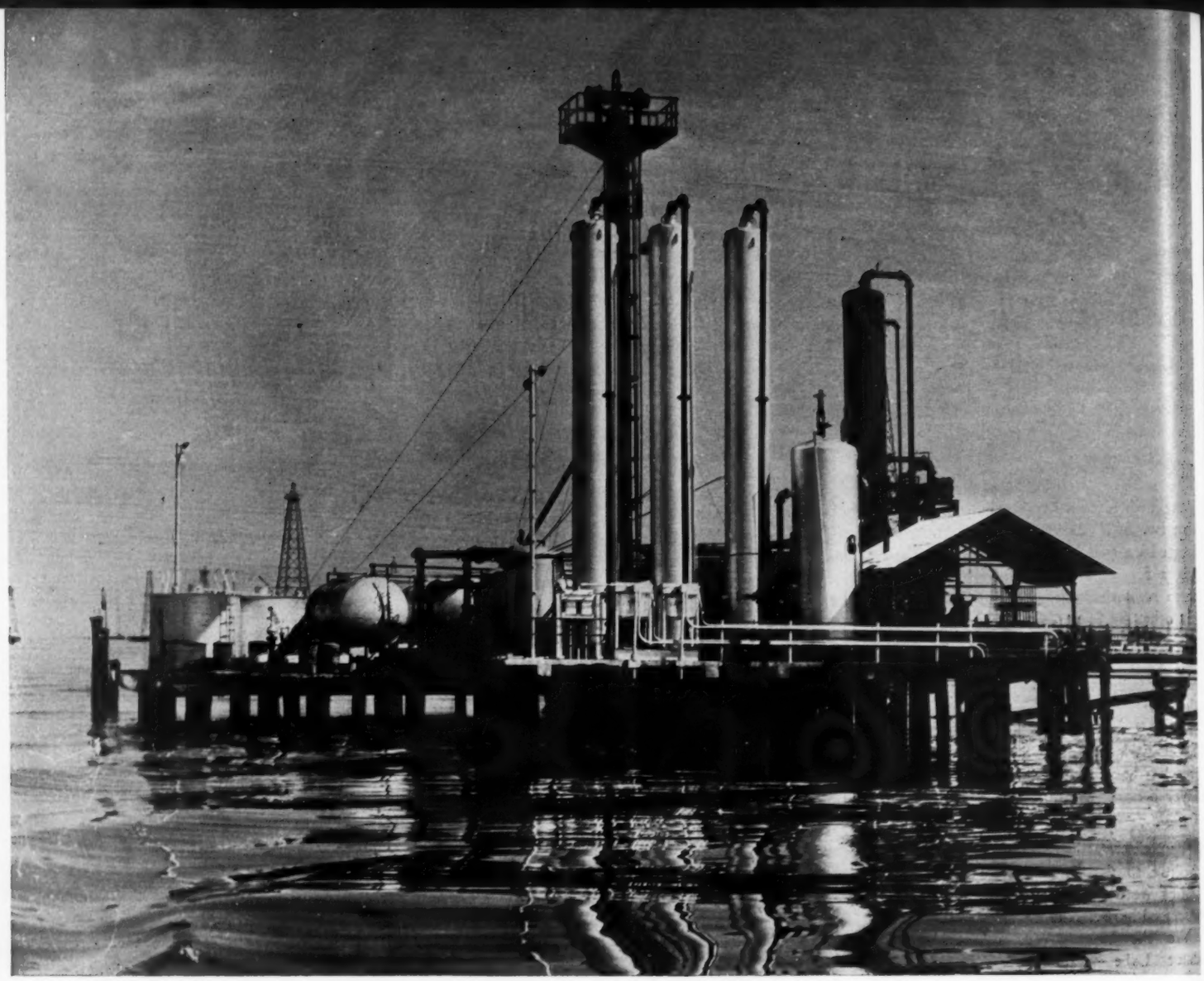
Skidding derrick shown at Oficina Field.

The method of figuring the value of the government's royalty oil is a great improvement. Various systems had been used before including a very complicated net-back system from the point of refining, and this gave rise to innumerable disputes and dissatisfaction. Now the value of the crude will be established in the field and computed on the basis of the world market price of similar crude.

The government is guaranteed a minimum value for its royalty oil based on a specific scale according to the gravity of the oil. This scale ranges from 68 cents per barrel for oil of less than 18 degrees API to $1.18 for oil of 42 degrees API and over. Formerly, it was specified that the government should receive a minimum payment of Bs 2.00 per cubic meter (10 cents per bbl.) regardless of the quality or selling price of the oil. Under the new law the price of royalty oil is determined, as previously explained, on the basis of market value of comparable grades adjusted for the cost of delivery to the shipping point. This automatically takes all factors into account.

Surface taxes have been so adjusted that oil companies can no longer hold large areas of land indefinitely but must develop them within a reasonable period. For the first ten years all concessions in exploitation must pay an annual surface tax (or rental) of five bolivares per hectare (62 cents per acre). During the next five years the tax is doubled and every five years thereafter it is increased by five bolivares per hectare until the end of the 40-year period for which concessions are granted. However, the operator is exempt from paying that amount above five bolivares per hectare per year which is equal to the total amount he has paid in royalty to the government for the year. In other words, the only operators who must pay the very high surface taxes are those who fail to develop their holdings.

However, the operator is given the opportunity, under an exploration concession, to explore for three years, paying surface taxes of only two bolivares per hectare annually (25 cents an acre). Also the operator during this exploration period can drill wildcat wells to prove up his



A natural gasoline plant in the middle of Lake Maracaibo, Venezuela.

property before converting it to an exploitation concession. This he could not do formerly.

The companies have been given the right to explore any lands outside their concessions or those reserved by the government at no charge. This they could not do before.

For the first time in Venezuela pipelines will become common carriers; however, a pipeline owner is required to move only that amount of crude for which he has capacity after he has satisfied his own crude requirements.

The new law provides for good conservation practices by being flexible in that the government can reduce the royalty rates and certain taxes if it is desirable.

Other phases of flexibility of the new law are that the government can reduce taxes and duties on refining and transportation in order to encourage these industry operations.

The old troublesome question "to exonerate or not to exonerate" has been solved by permitting no free imports except at the government's discretion for materials and machinery directly used in industry operations. This will be interpreted by the government as applying to new companies entering the country so that they will not be under a handicap. At the same time the government plans to revise its method of charging for import duties which is based on an antiquated weight basis. For example, the duty on an oil field truck now amounts to almost as much as its original cost, as duty is charged according to weight. A scale of reasonable duties will be worked out which will eliminate disputes and discrimination.

The greatest gain to both the country and the oil companies is that all the existing concessions will be converted to the new law. Although the companies will pay a much higher royalty and higher taxes they will receive in exchange clear title for a forty-year period to their present concessions, with a preferential right to an extension for a similar period. This is of particular advantage to the companies as in some cases their old titles are questionable and the government has legal claims against them. If these claims were pursued it would mean years of complicated litigation beneficial neither to the government nor the companies. Under the new setup all past claims on the part of either the government or the companies are relinquished and everyone is given an apportunity to start with a clean slate.

The companies will pay a tax for the privilege of converting their concessions to the new law. This amounts to six bolivares per hectare (75 cents per acre). However, under special conditions, if less than twenty years of the life of the concession has lapsed, a reduction can be granted but the tax paid cannot be less than one bolivar per hectare (12½ cents per acre), for each five years or fraction thereof that may have elapsed of the term of the concession.

It is estimated that as a result of this new law the income of the Venezuelan government from petroleum will be increased by approximately 70 percent. For example, during the year 1942, total receipts to the government from oil amounted to Bs 63,561,411.35 (approximately $19,261,033). If the new law had been in effect

the revenue from petroleum during the same year would have amounted to Bs 114,237,081 (approximately $34,617,300).

The companies' gain under the law cannot be figured as specifically as that of the government. For what the companies have gained is the guarantee that they can continue to operate in the country indefinitely and upon a stable basis.

The new measure must be regarded as a "ceiling" law. No further demands can be made upon the industry without the probability that Venezuelan oil development would receive a severe set-back. The royalty of 16⅔ percent plus concession taxes and taking into consideration all cost factors, including the probable life of the fields, represents an approximately equal division of profit between government and industry.

As matters stand the Venezuelan government will receive from 26 cents to 28 cents per barrel for its royalty. Approximately six cents of this amount represents income from taxes and other charges. In the future the government may find it necessary to reduce these charges in order to meet competition from other oil areas.

It is the hope of Venezuelan officials and oil operators as well that after the war when drilling can proceed unhampered the country's production may be increased materially. This of course will depend upon numerous factors such as costs in competing countries and the energy which they put into their development activities.

The highest production ever reached in Venezuela was in December, 1941, with an average of 750,000 bbl. daily. Due to war conditions production has been running about 400,000 bbl. daily. Considering that exploration has been kept down for the past five years it seems reasonable to anticipate that output will equal or exceed the best previous record.

One of the important effects of the new law is expected to be an acceleration of the industrialization of the country and the development of its other natural resources so that it will have a more balanced economy than heretofore. Venezuela is virgin territory for such new development and President Medina wishes to encourage additional foreign capital to come to Venezuela to work with the country. With the increased income which Venezuela will receive he plans to launch a program of sanitation works, increased transportation facilities (roads, rivers and railroads), national education, social security, irrigation and agricultural development and building up of a merchant fleet. Such a program, together with the entry of new capital to the country, the President believes, will assure a stable economy for Venezuela and the oil industry will prosper accordingly.

After the new law was passed, President Medina conferred decorations of the Order of the Liberator upon those members of the Venezuelan government who worked long and steadily on the new law. Chief among these were the Attorney-General, Dr. Gustavo Manrique Pacanins, who together with President Medina might well be called the father of the new law; the Minister of Fomento, Eugenio Mendoza, Jr., under whose direction the work was carried out; the technical and legal talent of the Ministry of Fomento—Dr. Angel D. Aguerreverre; Dr. Luis Herrera Figueredo; Dr. Carlos Perez de la Cova; Dr. Edurado Luongo Cabello and Dr. Juan Maturano Battiste; and the American engineers retained by the government, Herbert Hoover, Jr., and A. A. Curtice.

The President also gave a formal banquet for the government officials who had worked on the new law and for the oil company representatives in celebration of this triumph of government-industry cooperation.

SALIENT FEATURES OF THE PETROLEUM LAW

Introductory Principles

1. Everything relative to the exploration and exploitation of petroleum belongs to the nation.

2. The right of exploration, exploitation, refining and transportation may be acquired by concession from the government.

3. Concessions may be granted in accordance with the minimum terms outlined in the law or the applicant may offer more favorable conditions if he chooses to do so. The government can grant concessions to those whom it believes will best serve the interests of the nation, and is not necessarily bound to award them to the highest bidder.

4. Governments of foreign states or their dependent corporations cannot acquire concessions.

Exploration Concessions

1. Any person, natural or foreign, may explore at no charge any lands except those under concession or reserved by the government.

2. Exclusive exploration concessions are granted for three years, but may be converted into exploitation concessions at any time during that period.

3. During the exploration contract the concessionaire must pay a tax (rental) of two bolivares per annum per hectare (about 25 cents per acre per year).

Exploitation Concessions

1. At any time during the exploration period the concessionaire may select the land he wishes to exploit. This cannot exceed half of the land in the exploration contract. It must be divided into parcels, which cannot exceed 1,250 acres each, but can be grouped in any way the concessionaire desires, either checkerboard or forming solid blocks. The land given up becomes a national reserve.

2. When converting an exploration concession to an exploitation concession a tax of eight bolivares per hectare ($1 per acre) must be paid.

3. Exploitation concessions are granted for 40 years. Between the twentieth and the thirty-eight year of life of a concession, the government can grant the concessionaire a new term not to exceed 40 more years. New terms may be negotiated but they cannot be less favorable to the nation than the original ones. When the agreement is entered into, the concessionaire shall pay a special tax of not less than twenty centimos per hectare (2½ cents per acre) for each year the life of the concession is increased. If the original concessionaire does not wish to extend his concession under the terms the government shall state, it can be granted to someone else on those terms.

4. Sealed bids must be given to the government on all exploration or exploitation concessions desired. The bid which the government considers most favorable to the national interest will be accepted. Cash bonuses, additional royalty, etc., can be offered by the concessionaire.

5. In granting exploitation concessions, the government will take special care to avoid concentrations or groupings which would be contrary to national interests, i.e., tending to monopoly.

6. The government may put up national reserves for bidding as it deems expedient. Concessions reverting to the government—those not extended—may either be operated by the government, leased, or granted anew as exploitation concessions.

7. All exploitation concessions must pay an annual surface tax (rental) of five bolivares per hectare (62 cents per acre) for the first ten years. For the next five years the tax is ten bolivares per hectare per year ($1.25 per acre); fifteen bolivares per hectare per year ($1.87 per acre) during the following five years; twenty bolivares per hectare per annum ($2.50 per acre) the following five years; twenty-five bolivares per year ($3.12 per acre) the following five years; and thirty bolivares ($3.75 per acre)

during the remaining term of the concession. However, the concessionaire is exempt from paying that amount above five bolivares per hectare per year (62 cents per acre) which is equal to the total amount he had paid in royalty to the government for the year.

8. All concessionaires must pay an exploitation tax (royalty) of 16½ percent of all oil produced. The government may take this as it desires either totally or partially in kind or in cash. The government can reduce this royalty in cases when, due to increased production costs including taxes, it is no longer possible to produce the oil economically. The same royalty and conditions apply to production of natural asphalt and gas used as a fuel. However, no royalty is paid on gas used for repressuring or gas which cannot be utilized. Special arrangements can be made to determine the government's share for products obtained from processing gas.

9. In case the government decides to take its royalty oil in kind, it must be delivered, in all or in part, at any established receiving installation along the route over which the oil is normally sent. The government must pay for pipeline transportation at cost, but this not to exceed one-half centimo per cubic meter per kilometer (four cents per barrel per 100 miles); its concessionaire loads the government royalty oil for export, it must be done at cost and this not to exceed 20 centimos per cubic meter (one cent per barrel). The concessionaire must pay storage cost of government royalty for two months at most. At the end of that time the government will sell it to the concessionaire at the value set for royalty oil.

10. If the government decides to take its royalty oil in cash the value for it will be determined in the following way:

(a) The concessionaire must pay the market value of the oil in the field—this to be calculated by agreement on the basis of the world market price of similar crude.

(b) The only deduction to be made from the price as calculated at the Venezuelean port of embarkation is the cost of transportation from the producing field to the port. This cost shall be fixed by agreement but shall not exceed one-half centimo per cubic meter per kilometer (four cents per barrel per 100 miles) of pipeline distance.

(c) The price per cubic meter of petroleum in the field at a temperature of 15.56 degrees centigrade shall not be less than is specified in the law according to the specific gravity of the oil. This scale ranges from 68 cents per bbl. for oil of less than 18 degrees API to $1.18 for oil of 42 degrees API and over.

11. The government can at any time contract to sell its royalty oil to whomever it chooses, but at a price not less than the fixed minimum. Contracts cannot be made for longer than two years, at prices revisable every three months and payable monthly.

Transportation

1. Pipelines are common carriers and tariffs must have government approval. However, a concessionaire is obliged to carry another's oil only if he has capacity above his own requirements.

2. Concessions for transportation only may be granted for a fifty-year period, subject to extensions for like periods. (Exploitation concessions automatically carry transportation privileges.)

3. A transportation tax to be agreed upon must be paid to the government but it cannot exceed 2½ percent of pipeline transportation charges. This does not apply to a concessionaire's transportation of his own oil. The government may abolish or reduce the transportation tax if it deems it expedient for the public good.

Refining

1. Concessions for refining only may be granted for a fifty-year period subject to extensions for like periods. (Exploitation concessions carry automatic refining privileges.)

2. There is no export tax on refined products, but on those refined products which are consumed in the country, a tax must be paid equal to one-half of what the duty would have been if they had been imported.

3. The government can remit totally or partially the transportation taxes on petroleum used for refining if it deems it convenient.

4. Special refining agreements may be made and to encourage refining special benefits may be offered such as exoneration from import duties, exemption from taxes, etc.

Miscellaneous

1. In case the concessionaire obtains a price for petroleum, natural asphalt, natural gas and other hydrocarbons which is greater than the one used to calculate royalty price, he shall pay the government 16⅔ percent of the excess in price.

2. The government can at its discretion grant partial or total exoneration from import duties on materials, machinery, etc., which have a direct and immediate relationship with exploration, exploitation, manufacture, refining or transportation or obligational operational work or for protection of labor and installations.

3. Concessionaires are obliged to operate upon sound technical principles and to avoid waste.

4. Concessionaires must keep in Venezuela all accounts relative to their industrial operations. They must give all data to the government regarding the development of the industry. This is to include ample geological and geophysical information concerning the regions studied and wells drilled, this to be given within a year from time of when the work is done.

Conversion or Adaption of Concessions

1. Concessions granted under other laws may be adapted or converted to this new law. Intention to convert must be filed within two months. Adaption of concessions means simply placing them under the regulations of the new law but with the same life and title as before. However, if concessions are converted, clear title is given and the concessions are in effect for a new 40-year period.

2. Upon converting a concession a tax must be paid of six bolivares per hectare (75 cents per acre). If less than twenty years of the life of a concession to be converted has elapsed, a reduction can be granted but the final tax cannot be less than one bolivar per hectare (12½ cents per acre), for each five years or fraction thereof that may have elapsed of the term of the concession to be converted.

3. Payment of taxes, royalty, etc., on converted concessions will be retroactive to the date the law was published (March 15, 1943).

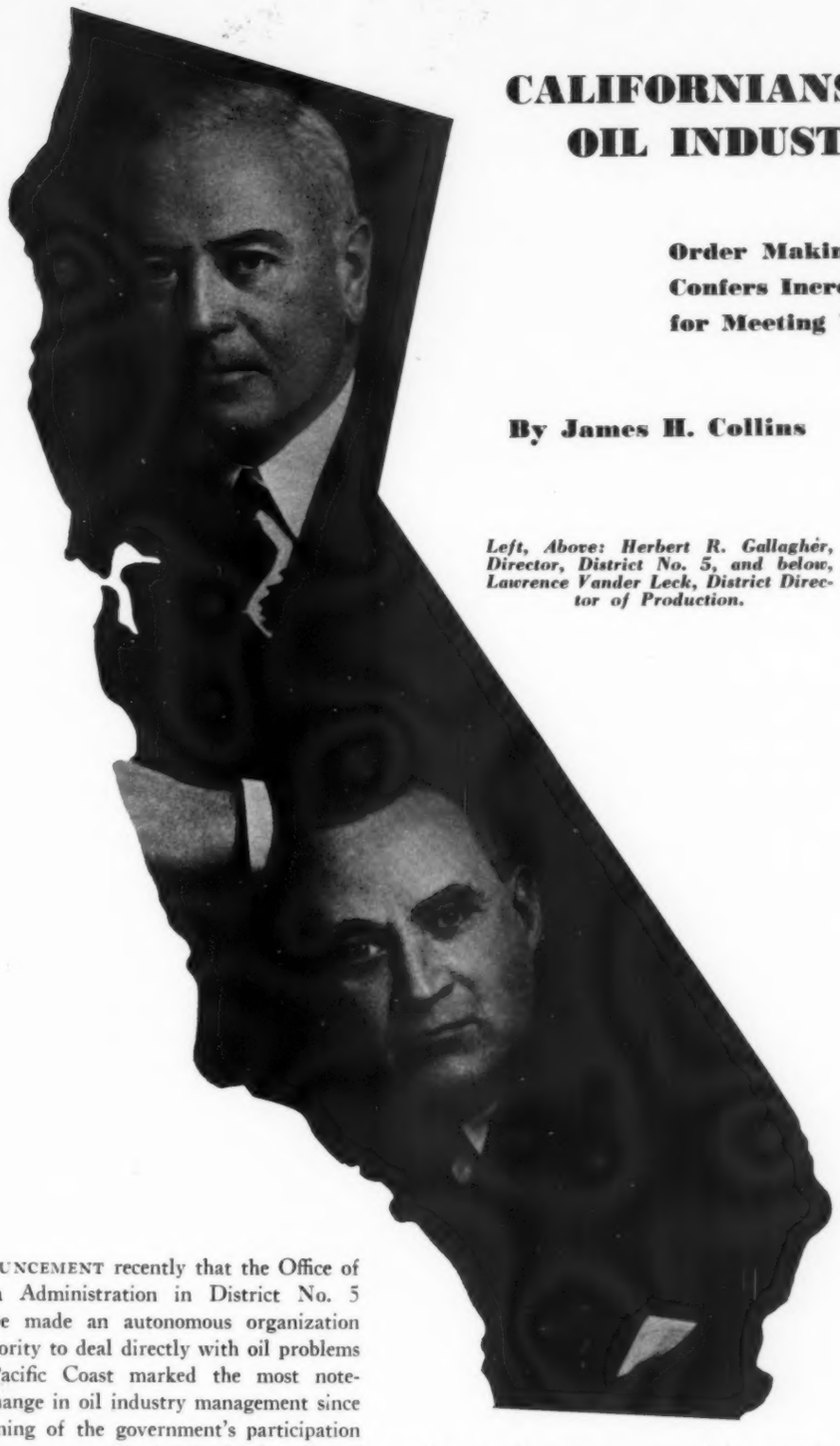
4. Upon conversion, all actions and claims, known or unknown, on the part of the government or the concessionaire shall be renounced. This does not apply to arrears in taxes or acknowledged debts.

Consolidada de Petroleo pipe line entering terminal property.

CALIFORNIANS DIRECT EXPANDED OIL INDUSTRY OPERATIONS

Order Making PAW District Five Autonomous Confers Increased Authority and Responsibility for Meeting War Requirements of Pacific Area

By James H. Collins



Left, Above: Herbert R. Gallagher, Director, District No. 5, and below, Lawrence Vander Leck, District Director of Production.

ANNOUNCEMENT recently that the Office of Petroleum Administration in District No. 5 was to be made an autonomous organization with authority to deal directly with oil problems of the Pacific Coast marked the most noteworthy change in oil industry management since the beginning of the government's participation in it two years ago. Previously the function of the district offices had been limited to making reports and recommendations to Washington and to carrying out instructions received from headquarters there. In conferring broader authority upon the district office located in Los Angeles two objects were in view.

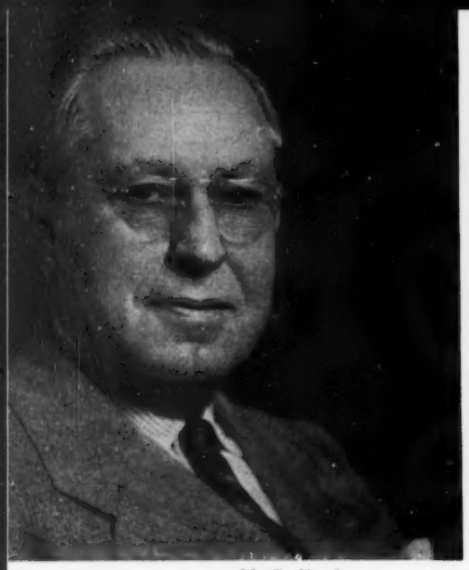
In the first place it recognized the place of special importance occupied by California as the main source of oil supply not merely for the Pacific Coast but for the entire Pacific war area. Tremendous demands for fuel for the planes, the ships and the land forces of the allied nations in the vast area covered by operations against Japan had to be supplied from this area. Failing that it could only be obtained from the Mid-Continent and the Gulf Coast through the Panama Canal, involving a heavy increase in shipping requirements impossible to meet.

Secondly, besides the time-saving importance of having problems settled on the spot, immediately, by oil men, Petroleum Administrator Harold Ickes and Deputy Administrator Ralph K. Davies planned this office as a model of decentralization, to be followed in other regions, and possibly by other Washington war bureaus.

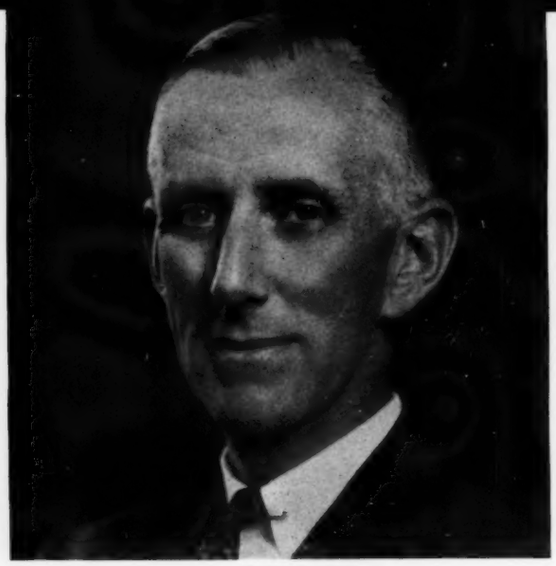
In connection with its new responsibilities, a number of changes were made in the operating staff. From exploration to distribution, every phase of the industry is covered by the different divisions of the organization, each one in charge of an oil man who is outstanding in his special field. Most of them in fact have been drafted from key jobs with oil companies. One notable exception is the newly appointed director, Herbert R. Gallagher, who was called from retirement to take up the post. Well known to the industry nationally as well as on the Pacific Coast, he has had a long and varied experience in oil. From 1911 until 1932, Mr. Gallagher (who eliminates the second "g" in pronouncing his name) was senior vice-president of the Shell Oil Company in California, and responsible for the building up of its marketing organization at a time when new and aggressive methods were being developed by California competitors. In 1932, when the Consolidated Oil Company was formed by merging the Prairie Oil and Gas Company and the Prairie Pipeline Company, with the Sinclair companies, he went to New York as president of the Consolidated, remaining until the fall of 1940, when he retired to live again in California. He was chairman of the general committee of Region One under the NRA. During World War I, he was a member of the Petroleum War Service Board. And he has been a director of the American Petroleum Institute since its inception in 1919.

Until Mr. Gallagher's appointment, and the clear statement of PAW policy made at the time, the vast majority of all oil operations on the Pacific Coast had to be handled either through Washington, or as exceptions to Washington regulations. Serious delays arose in matters pertaining to the use of critical materials for new development and production.

"By his action in Washington," said Mr. Gallagher, "Administrator Ickes has flashed the green light to the California oil industry to go ahead with an operations program which has only one objective—that of increasing the production of crude petroleum to the limits required by the war program."



M. F. Youker.



C. B. Garretson.

K. L. Reynolds.

This objective is furthered by two methods:
(1) The utmost simplification of regulations under which the industry has hitherto operated.

(2) The placing of regulations, within defined limits, in the control of the men who have been enlisted for District 5.

Much of the delay and uncertainty with a substantial part of the paper work, will be eliminated, and it will no longer be necessary for California oil men to look to Washington, much less travel there, in order to know what procedure they may follow. They will have the right of appeal against any decision of the Los Angeles office, a privilege not likely to be exercised when oil men work with oil men to the one end of increasing production, and greatly stepping it up with the carrying of the war to the shores of Japan.

Under orders already issued, the vast majority of California fields are defined as to separate pools, by electric log points and geological formations, in foot depths. A standard 5, 10, 20 or 40-acre pattern for new wells in each of these pools is established, requiring no further authorization to be eligible for priorities. Standards are established for reworking or rehabilitating old wells with the same automatic priorities. Standards for directional drilling, pumping and lift equipment are also established. Gas wells and pools where a gas cap exists are not exempt from the general terms of PAO No. 11, but exceptions will be decided upon for prompt working with utilization of maximum gas energy.

"Operators can now plan long range programs with more definite assurance," said Deputy Administrator Ralph K. Davies. "The liberal provisions should result in the rehabilitation of many idle wells. The standards for installation of pumping or other artificial lifting equipment are less restrictive, and production increases are confidently expected from this source. I am confident that the solutions to California's oil problems will be worked out speedily and efficiently on the ground."

The appointment of Lawrence Vander Leck, former Shell and Consolidated executive to the direction of the Pacific Coast office, before the announcement of autonomy came from Washington, was regarded as a big step toward real decentralization.

Well known in the industry, his Dutch name gives no hint of his old California ancestry, for his people came round the Horn in the rancho days, and married into the country. He was born in Los Angeles, in 1890, was graduated from high school in 1911, and as a B.S. in geology at the University of California in 1915. Going to work immediately for Standard of California in its producing department, he put in a year, and then got into the California State Mining Bureau, in what is now the division of oil and gas; became deputy supervisor of that division; geologist for the bureau in 1919, and wrote Bulletin 89, "Petroleum Resources of California."

In 1920, he became associated with the Fullerton Oil Company, and was vice-president of that company when asked to assume the position of Director of Production for the Fifth District. His activities in the industry have been outstanding. He was a charter member of the original curtailment committee set up in California in 1930; was chairman of the curtailment body then known as the Central Committee of California Oil Producers, from 1936 to 1941; was president of the Oil Producers Agency in 1941, 1942 and part of this year; was a member of the Petroleum Committee of District 5 from its inception; was president of the Oil Producers Agency; was a member of the Petroleum Industry War Council; is director of the Independent Petroleum Association of America, and also of the California Oil and Gas Association, and was secretary and director of the Waste Water Disposal Company, which is regarded as having done an advanced job in operating central plants for the cleaning of refractory oil field waters.

In charge of refining is Malcolm F. Youker, selected in November. He was born in Santa Rosa, California, in 1886, graduated from high school there, took his B.A. in engineering at Stanford University, and began work in 1910 as construction engineer for the Associated Pipeline Company of California, at Taft. Then he served successively with Standard of California as refinery construction engineer; with the U. S. Bureau of Mines as refinery experimental engineer; with Waite Phillips Company as manager of manufacturing; with Alamo Refining Company as vice-president and general manager; with Phillips Petroleum Company as director and vice-president in charge of refining. He has developed and patented numerous refining processes mostly with particular reference to thermo polymerization; he retired from the Phillips Petroleum Company and came to California in June, 1942.

Heading the marketing division is Charles B. Garretson, born in Pasadena, California, in 1895, who studied business administration after graduating from Oakland high school in that city. Going to work in a Standard of California warehouse in 1916, he became a service station operator and salesman; was commissioned an ensign in the Navy, 1917-18; went to work as salesman for the Richfield Oil Company after that war, and by 1931 was vice-president and assistant manager of sales. His work for the industry, dealing mostly with marketing problems, has included assistant general management of the Pacific Coast Petroleum Agency, and executive secretaryship of the Regional Code Committee. Ralph Davies called him to Washington following the establishment of OPC in July, 1941.

Natural gas and natural gasoline are in charge of Kenyon L. Reynolds, who since 1915 has been associated with that branch of the industry, designing, constructing and operating compressor plants, pipelines, gathering systems, gas traps, refrigeration plants, oil absorption plants, charcoal absorption plants. He got his B.A. in civil engineering at the University of California; was chief chemist, superintendent, assistant general manager, and vice-president and general manager of the Wallace Refineries, of California. (The late Walter J. Wallace was the "father" of casinghead.) He went to the Pacific Gasoline Company of California in 1922 later becoming

C. T. Reichert.

E. G. Trostel.

Clyde Thomas.

vice-president and general manager, in charge of 28 natural gasoline plants, and in 1926 became independently active in the industry.

Robert W. Ducker, of Tulsa, Oklahoma, was appointed at the same time as Mr. Reynolds, as natural gas analyst in that division, coming from the general superintendency of the Oklahoma Natural Gas Company, Tulsa. Studying civil and petroleum engineering at Oklahoma A. & M., and Oklahoma University, he has been active in oil and natural gas for nineteen years. Mr. Ducker is stationed in Washington.

The facilities security division is in charge of George F. Prussing, born at Highland Park, Illinois, in 1891, educated at the Chicago Latin School and University of Michigan (B.S.C.E. 1915), and entering the oil industry in 1919 after experience with the Ford Motor Company, and Southwestern Shipbuilding and Drydock Company, of San Pedro, California, as plant engineer. He had worked 22 years for the Union Oil Company of California when beckoned to his present post, being a general engineer in charge of safety, fire prevention and pressure vessel inspection. He was secretary 1941-42 of the Oil Industry Protection Committee and Western Region Committee on Protection of Petroleum Facilities, PIWC.

The materials division is headed by Charles T. Reichert, who was born in Belvedere, Illinois, in 1900, went to high school and night school, became a "roughneck" for the Dominion Oil Company in California at 16, and after positions with the Associated Oil Company, Grant Oil Tool Company and Petroleum Equipment Company, became associated with the National Supply Company; his experience has thus been mostly in oil production and refining equipment.

Director of the transportation division is L. E. Fleming, who joined Standard of New York upon graduation from the University of California in 1915, was engaged in administrative marketing and distribution in China until 1924; then went with Standard of California, and became general manager of transportation in 1934, which position he left to join PAW. He was appointed Pacific Coast Industry member of the Tanker Control Board organized in August, 1941, and during the past fifteen months has been chairman of the Navy Contact Committee, a subcommittee of the District 5 transportation committee. He is a native of Franklin, Pennsylvania, and lives in San Francisco.

Director of the reserves division of conservation engineering is Everett G. Trostel, a Californian, petroleum engineering student at "CalTech," University of California, and the University of Southern California; going to work in the refinery division of the Union Oil Company in 1933; then the field department in 1935, as petroleum development and production engineer: he is an author of API papers, and has lectured on petroleum engineering at U.S.C.

District 5 counsel, dealing with the many legal problems involved, is Clyde Thomas, born in Kentucky in 1893, but living in California since boyhood; graduate in law of the University of Southern California; sixteen months in France in the air corps during the first world war; in private practice in Los Angeles, with oil industry experience, and attorney for the Conservation (Central) Committee of California Oil Producers.

To these men together with members of the staff surrounding them has been entrusted the leadership of a movement designed to carry oil production in the Pacific Coast area to a new high level and to enable it to meet the ever increasing demands imposed upon it by the intensification of war activities across the Pacific.

WAR AND OIL ON THE PACIFIC COAST

When the Japanese brought war to Pearl Harbor the oil industry of the Pacific Coast, along with much else in that region, underwent a series of notable changes. It became immediately apparent that the California oil fields would be practically the sole source of fuels for large-scale naval, aviation, and military land operations in the Pacific. New industrial plants for the production of war material sprang up and created new demands for power and heat, demands which only the petroleum industry of the Coast was in a position to supply.

The first difficulty arose in the transportation field. The transport of large bodies of men and huge volumes of military material congested the shipping facilities by land and sea. For a time the oil industry was seriously inconvenienced by the presence of Japanese submarines off the coast, which made tanker transportation of oil a hazardous business, and it was not long before all tankers went into service controlled by the military. This bore heavily on the refineries, which are mostly concentrated in the San Francisco Bay and Los Angeles areas. Aside from some pipe lines that run direct to these areas, the refineries had been obtaining much of their oil through pipe lines over the Coast Range from the San Joaquin Valley to sea terminals, where it was picked up by tankers for further transport. Withdrawal of the tankers compelled a rearrangement and pooling of existing pipe line facilities. The situation was greatly helped by converting a 22-inch pipe line from the Kettleman Hills to the San Francisco Bay area from carrying gas to transporting crude oil. Since then the oil transport situation has been more satisfactory.

The conversion of the 22-inch pipe line, however, necessitated providing the San Francisco Bay area with another source of gas. This was arranged by laying additional lines to the Rio Vista gas field and increasing the dry gas production of that district.

The increase in fuel gas demand was complicated also by the necessity for a change from a

Left: Shell's Verne Community No. 1; carefully enclosed and insulated because of being built within the residential area of Los Angeles.
Above: Workmen making hose connection with swivel at St. Helens petroleum lease.

"gasoline economy" to a "fuel oil economy." Previous to the war the gasoline market provided the chief demand for oil production, resulting in a reduced demand for low gravity oils which are low in gasoline and high in fuel oil. The war reversed this situation, resulting in a heavy demand for fuel oil and reducing gasoline demand. Since the high gravity oil wells are the source of major proportions of natural gas this change had a marked effect on the gas supply.

When the war broke out the petroleum industry had become largely geared to curtailment, which was imposed to limit the supply of crude oil to the effective demand, and to establish efficient methods of oil production that would ensure greater economic recoveries. Under this regime the oil wells were producing nearly enough gas to meet the pre-war requirements, leaving very little demand upon the dry gas fields. There was, in fact, an oversupply of dry natural gas, so much so that the gas wells operated only in the winter months and were mostly shut down during the slack summer season. This situation was changed by the increased demand occasioned by the war. Production of dry natural gas is now an all-year affair, and it became necessary to make additional provision for peak loads.

This was done when the government commandeered a depleted oil sand in southern California for gas storage in anticipation of peak demands. This gas storage reservoir has an effective capacity estimated at about two billion cubic feet.

At present the oil wells that produce gas are doing little to help out the gas storage, because gas production must be limited to the amount needed for energy to lift the oil. A greater rate of gas production would greatly reduce the ultimate oil recovery. In fact, it is being found necessary to shut in gas-cap areas in order to assure continued oil production, with the result that oil production is increasingly thrown on the black oil areas. The net result is that the total available gas supply has to be carefully managed to avoid local shortages. During the past winter the operation of a government limitation order restricted the addition of gas domestic space heating in some areas. The usual curtailment of gas to surplus industrial consumers has been necessary during the heating season, but the situation on the Pacific Coast is in no way comparable to the fuel oil situation in the East.

In the meantime, the accelerated consumption of oil is cutting into California's oil reserve, and discoveries are failing to keep pace; no first rate new oil fields have been found during the past four years. During this period most of the wells completed have been shallow holes drilled in proven areas to produce the heavy oil that can be used for fuel without elaborate refinery treatment, and for which there is an insistent demand. These wells were designed to meet an emergency, and their effect will be to accelerate the depletion of the reserves of heavy oil, which were none too great to begin with. In view of the general oil situation the government has been calling for more drilling and for greater production of light oil. The state allotment has been raised repeatedly by the Petroleum Administration for War until now it is nearly 800,000 barrels per day and is passing the point at which present wells can produce without serious injury to the ultimate recovery.

The necessities of the war brought about a change in methods of allocation of production. Previous methods were based upon a uniform formula which distributed oil largely on a depth basis. Current methods of allocation which have been gradually worked out by oil industry groups in cooperation with the Petroleum Administration are designed to serve as nearly as practicable, actual demands for military and civilian war products. The only limitations are that fields are not permitted to produce above their "maximum efficient rates." The rate is defined as the

highest rate of production that a pool can maintain for a period of six months without jeopardizing the maximum ultimate recovery from the reservoir. This rate has been the subject of careful study by a selected group of engineers. Where the operators in any given pool have agreed on a method of intra-pool allocation such methods have been approved by the Production Industry Committee of District Five and by the Petroleum Administration. These formulas are believed to be very beneficial in promoting production along lines of good conservation practice and should result in marked increase in ultimate production of those reservoirs to which they have been applied.

The number of wells in process of drilling has continued to fall off. PAW is now making every effort to accelerate the rate of drilling. Well spacing restrictions which have been necessitated by the shortage of materials during the first year of the war are being modified and the procedure for the authorization of drilling programs is being simplified. This should also stimulate wildcat drilling which is still going on, even though on a reduced scale that has been imposed on the one hand by the scarcity of oil-field supplies, and on the other hand by the adverse economic situation. Much of the steel that is obtainable is going into the shallow fields of the San Joaquin Valley for the production of heavy oil. Beside this decreased rate of new drilling, the prevailing low prices have kept many marginal and near marginal wells out of production which otherwise would be repaired and put on the pump again. Late in March a new price ceiling on California crude was announced by OPA. This allows an increase of twenty-five cents per barrel on oil of 15 gravity and grades down for lighter crudes. No increase is allowed on crude of more than 25.9 gravity.

The actual state of drilling in California appears in the reports of the Oil Administrator's Office, which shows that in 1942 there were 570 completions as against 941 in the year 1941. At last account the estimate of California reserves at the beginning of 1943 stood at 3,169,096,345 barrels for oil and 10,850 billion cu. ft. for gas. The daily production of oil during December, 1942, was 758,787 barrels.

Among the new producing areas that have been recently added are the Riverdale field in Fresno County (an Amerada discovery) in which a number of wells have been completed at the 6800-ft. level; the Williams field (Shell) in the Antelope Hills region; the Buena Park field (Texas Company); an extension of the Aliso Canyon field (Tidewater Associated); a new field east of the Strand field and a new field—the Zaca—north of Los Olivios in Santa Barbara County (both of these also by Tidewater Associated). A recent oil discovery is that of the Pleasant Valley Area of Coalinga where the Gatchell sand which has proved so productive in the Coalinga Nose field has been successfully tested (Standard of California). A new gas field, the Bowerbank, was discovered by the Texas Company.

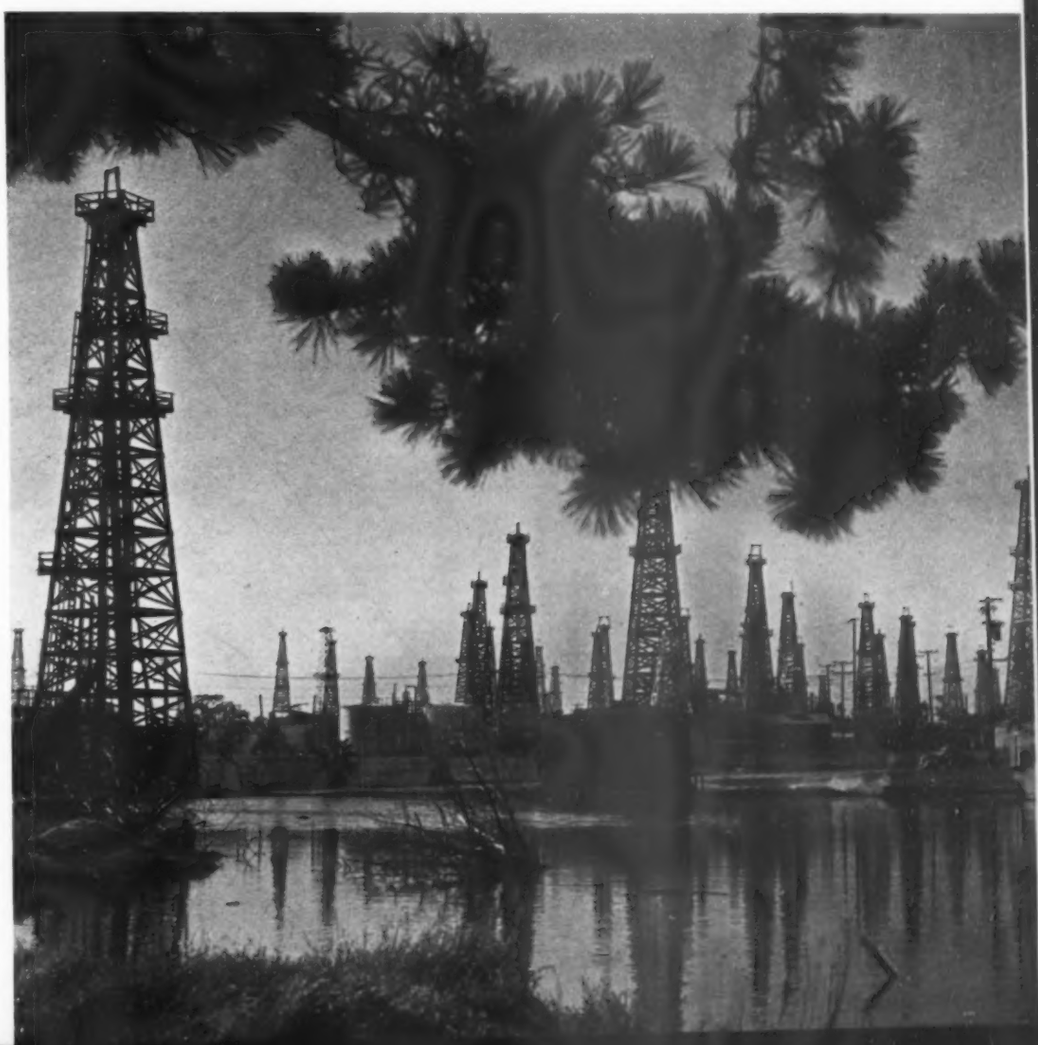
Recently there have been signs that new drilling in California may take at least a small spurt. Since the beginning of this year the number of notices of intent to drill filed with the California oil authorities has noticeably increased over the comparable period of last year, and drilling contractors have reported an increase in bids from oil companies for projected new wells. Most of these new projects are for areas where the holes are expected to be shallow. A recent government survey has indicated a large number of sites in old fields that might be drilled with advantage. New wells in these areas will be encouraged by the modifications in spacing restrictions already mentioned.

As for the California refineries, the demands of war have affected them to about the same degree as refineries elsewhere in the United States. Gasoline rationing to conserve rubber has reduced the use of motor fuel by civilians. Like other refineries, they have been required to produce large volumes of high octane number gasoline and fuel oils, though the ready suitability of California heavy oil for use as fuel after topping has somewhat lightened the task of these refineries. Taking one thing with another, the refiners are able to maintain production.

On the other hand, mortality among roadside gasoline stations, restaurants and trailer camps, which catered to California's extensive tourist traffic, has been extremely heavy.

Secretary Harold L. Ickes, first as Petroleum Coordinator for War and more recently as Petroleum Administrator for War, together with his deputy, Ralph K. Davies, has been and is now watching and keeping all these conditions constantly under observation. They recognize the importance of petroleum in the conduct of war in the Pacific and that war needs can only be supplied by a healthy, vigorous and prepared industry. Every effort of the Petroleum Administration has been directed to helping that industry to be ready and able to meet and supply each and every war demand whenever it might arise. To better accomplish this end, Mr. Ickes and Mr. Davies have decentralized the Petroleum Administration so that its administration on the Pacific Coast is now conducted by the District Five Office at Los Angeles under the leadership of Herbert R. Gallagher, the newly appointed District Director in Charge. This will eliminate the need for members of the industry to make frequent trips to Washington, with the inevitable delays occasioned thereby. Mr. Ickes and Mr. Davies are giving the Pacific Coast petroleum industry an opportunity to do its own war job.

Drilling activities are being intensified in California fields.



OIL COMPANY EARNINGS DECLINE

Under Impact Of War

Higher Operating Expenses with Reduced Volume of Domestic Consumption Cut 1942 Net Income—Similar Conditions Indicated for Current Year.

IN spite of war-imposed restrictions affecting virtually every department of its activities, the American petroleum industry was able to maintain a fair average of earnings in 1942. These profits are not as high as they were in some prewar years, but they are adequate to enable the payment of moderate dividends to stockholders.

Curtailment of domestic use, increased transportation costs and changes in refinery operation have reduced the volume of business and increased expenses but these added costs have been to some extent covered by payments from the federal government as a recompense for expenditures directly due to war conditions. At the same time there has been of course a very heavy demand for the special petroleum products demanded for military operations. Looking ahead to the remainder of this year, the indications are that the industry will experience a continuance of conditions similar to those that marked its course during 1942 barring unforseen changes.

Factors which could exert an adverse influence on profits include:

(1) A reduction in the depletion allowance which again is threatened by administration officials in their zeal to bolster tax revenues;
(2) Higher federal income or excess profits taxes;
(3) Increased operating costs without corresponding offsets in the form of higher prices for products; and,
(4) Renegotiation by the government of War, Navy and Maritime contracts held by many companies, so that their profits on product sales may be substantially curtailed, or virtually eliminated.

Demand for petroleum products thus far in 1943, on estimates, shows a reduction of from 10 percent to 15 percent against the similar period of 1942. Meanwhile, crude oil demand has been about on a par with a year ago. For the remainder of this year forecasts are that total demand for all products will be slightly higher than in 1942. Companies engaged primarily in crude oil production, including those integrated companies with more production than they require in their refinery operations, as well as those with a substantial part of their own production, are in a better position from the standpoint of earning profits. Company-owned production is cheaper than that purchased from outside sources. Refinery changes such as those for increasing yields of lower priced products against higher priced products thus would be less of a burden upon companies with a maior part of their own production. This is especially true since the establishment of ceiling prices by the government.

For the first three months of this year the profits of 27 companies issuing reports, and whose shares are listed on leading securities exchanges, revealed a small improvement as compared with the same period in 1942. These profits aggregated $41,719,359, an increase of 6 percent compared with $39,338,722 in the first quarter of last year. In the latter period two companies suffered small deficits. All the producing companies reported larger profits incident to higher production or reduced drilling expenditures in line with governmental restrictions on exploration activities. Of the 27, increased profits were shown by 19 and reductions by eight. The accompanying tabulation shows the 27 companies with their first quarter profits for 1943 and 1942, together with per share earnings on outstanding common stock, after allowance for preferred dividends in the case of those companies which have such stock.

An outstanding topic of discussion currently is crude oil prices. For almost two years a higher level of prices has been sought to furnish the incentive to drill and increase the nation's crude oil reserves, and to compensate operators for higher labor and material costs, as well as for more onerous taxes. Thus far the industry's efforts have been fruitless. Only two months ago Price Administrator Prentiss M. Brown rejected a recommendation of the Petroleum Administrator for War that prices be advanced by an average of 35 cents a barrel, with corresponding adjustments in products prices. The recommendation was formally made on April 7, one day before the President's issuance of the "hold-the-line" order on wages and prices to avoid inflationary tendencies. The OPA based its rejection on the President's order, but suggested, as an alternative, that the government subsidize the drilling of wildcat wells. In return for the subsidy the government would take one-fourth of the oil produced from successful wells for its compensation, but would bear the cost if the well proved a failure. Both the rejection of the price increase, and the subsidy proposal of the OPA were severely criticized by the industry and governmental officials. The subsidy was characterized as impracticable and tantamount to the government's entrance into the oil business. Last month the Petroleum Administrator for War re-recommended to the Office of Price Administration that crude prices be increased by an average of 35 cents a barrel. He intimated that if another rejection is made he may be forced to take the matter up with Economic Stabilization Director James F. Byrnes who in any event would have the final say on price changes under present conditions.

Failure to find sufficient new oil reserves—not merely upward revisions for existing pools—is cited as the chief reason for authorizing a higher crude oil price, aside from increased drilling costs. During 1942 official estimates of new oil discoveries range from 19 percent to 22 percent of the 1,400,000,000 barrels withdrawn from the ground in that year. In essence, five times as much oil was taken from the ground

Net Profit and Per Share Earnings for 27 Representative Companies
(Three Months ended March 31)

	1943		1942	
	Net Income	A Share on Com.	Net Income	A Share on Com.
Amerada	$ 944,221	$1.20	$ 698,287	$ .89
Atlantic Refining	1,333,584	.45	1,237,035	.41
Barnsdall	896,556	.40	775,248	.35
Continental	3,335,475	.71	3,544,165	.76
Darby Petroleum	244,204	.69	170,708	.49
Houston Oil	372,261	(*)1.04	512,689	(*)1.43
Lion Oil Refining	250,819	.58	254,194	.58
Margay Oil	107,729	.72	100,000	.67
National Refining	76,625	(*)1.29	187,742	(*)2.96
Ohio Oil	3,124,079	.46	2,953,075	.40
Panhandle Pdcg. & Refg.	58,138	.06	35,046	.04
Phillips Pete.	3,597,334	.80	3,364,551	.76
Plymouth Oil	548,512	.52	464,276	.45
Seaboard Oil	495,098	.40	270,930	.22
Shell Union	5,067,188	.39	4,656,546	.36
Skelly Oil	1,231,925	1.25	1,300,036	1.32
Standard Oil (Calif.)	6,410,246	.49	5,456,952	.42
Standard Oil (Ohio)	1,211,232	1.40	1,153,417	1.32
Superior Oil Corp.	45,421	.03	(d) 21,540	...
Tide Water Associated	2,656,797	.33	3,199,038	.41
Texas Co.	8,000,000	.73	7,900,000	.73
Texas Gulf Pdcg.	96,855	.11	106,809	.12
Texas Pac. Coal & Oil	220,330	.25	286,552	.30
Union Oil	1,275,930	.27	728,380	.16
Universal Consol. Oil	43,745	.24	31,085	.16
H. F. Wilcox Oil & Gas	65,058	.15	(d) 6,559	...

(*) On preferred stock.
(d) Deficit.

as was discovered in new fields. Moreover, crude oil has been selling out of line with other commodities. Based on the index of the Bureau of Labor Statistics, which uses 100, or par, for 1926, the current average crude oil price stands at about 62. Against May, 1941, when a general increase was made, the increase amounts to 10.7 percent. For all commodities used by the Bureau, the increase in the same period amounts to 44 percent, with farm products currently showing an increase of 37 percent against May, 1941.

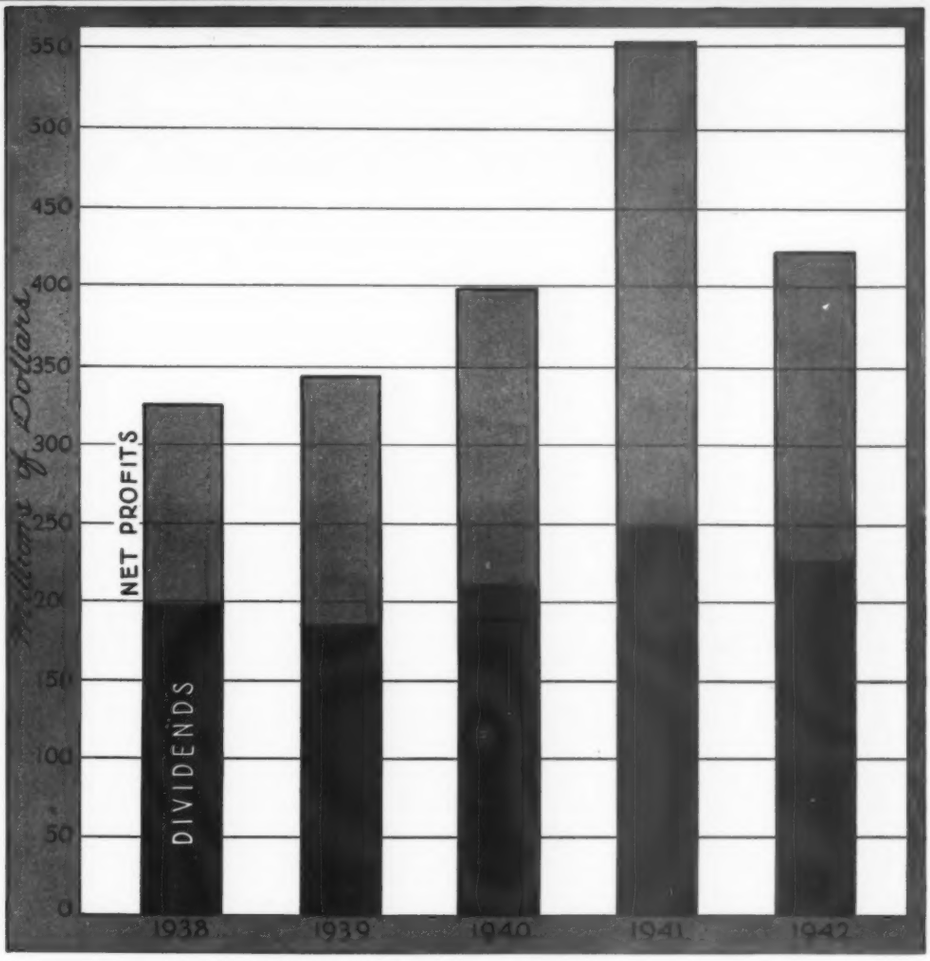
The battle for higher crude prices is continuing and the industry is confident that, in time, national necessity will compel an increase in present artificially controlled rates. Lacking an incentive in the form of better prices, it is inevitable that the nation's crude oil reserves will be drained further with the possibility that a shortage will develop within the next year or two. The reserve position, considered from the standpoint of economic production, does not augur well for the post-war period unless new and large discoveries are made meanwhile.

On present conditions it may be necessary to meet domestic demand, to import sizable quantities of petroleum from Latin American countries, probably at higher prices. In addition, the United States stands to lose an export market of approximately $400,000,000 which it had in oil in pre-war years.

For the first full year of war operation, during 1942, the oil industry in the United States acquitted itself well despite the mounting problems. The latter included, for instance, transportation shortages, especially tankers which provided the medium for delivering 95 percent of the East's oil supplies in normal times; a changeover from a peace to a war time basis; adjustment of refinery yields to produce larger quantities of fuel oil to the detriment of gasoline, the money crop; nationwide rationing of gasoline and, in many areas, of fuel oil; marketing troubles; and virtually full regimentation by the government.

In face of those difficulties the industry came through 1942 with profits only 20 percent less than in 1941. It disbursed cash dividends to equity stockholders only 5 percent smaller than in the previous year. For twenty-three American companies used in WORLD PETROLEUM's annual financial review, net profits in 1942 aggregated $422,042,000 against $554,044,000 in 1941. The record year was 1937 when these companies earned $607,404,000. Companies with substantial stakes in the eastern area, where products shortages were more severe than in other areas, were hardest hit from the standpoint of profits.

Standard Oil Co. (N. J.), the world's largest oil company, came through 1942 with a curtailment of more than 40 percent in net income, a reflection of restricted Atlantic seaboard operations, a sharp cut in production in Venezuela incident to submarine activity in the Caribbean, and destruction of properties in the Dutch East Indies where it had a joint interest with Socony-Vacuum Oil Co., Inc.



Profit and dividend trend for 23 representative oil companies over the past five years.

Socony-Vacuum, likewise an important operator on the east coast where 40 percent of its normal gasoline market exists, suffered a reduction in 1942 profits of close to 30 percent; Sun Oil Co. of 48 percent; Gulf Oil of 31 percent; Texas Co. of 32 percent; Atlantic Refining Co. of 52 percent and Tide Water Associated Oil Co. of 32 percent.

Of these latter companies, four reduced their dividend payments in 1942; namely, Atlantic Refining paid a total in cash of 70 cents on common stock against $2 a share in 1941; Standard Oil Co. (N. J.) $2 against $2.50; Texas Co. $2 against $2.50; Tide Water Associated 70 cents against $1. The remainder paid the same rate as in 1941, except for Sun which, in 1941, also provided for a stock dividend in addition to the cash payment of $1 a share.

Dividend payments in cash on equity holdings of these companies (23) aggregated $224,847,000 in 1942 against $248,675,000 in 1941, a reduction of 5 percent. Eight companies reduced their dividends, 14 were unchanged, and one increased dividends last year. The latter was Mid-Continent Petroleum Corp. which paid $1.40 a share of capital stock against $1.15 in 1941.

Aside from the four companies mentioned above which paid less in 1942, Phillips Petroleum disbursed $2 a share against $2.25 in 1941; Standard of Ohio $2.25 against $2.50; Standard of Indiana $1.25 against $1.50 and Skelly $1.25 against $1.50.

Funded and long term debts of the 23 companies, incident to the necessity for borrowing by some to expand production of war products, hit a new high record for many years past. As of December 31, last, this debt stood at $1,059,098,000, an increase of $86,057,000 compared with a year earlier. Twenty companies reported such debt last year, the same number as in 1941, although one company, Seaboard Oil Co., acquired a debt in connection with its acquisition of another oil company, while Barnsdall Oil Co. entirely liquidated its debt during 1942.

Working capital position of the companies registered a sharp improvement at the end of 1942, the total for the 23 companies standing at $1,932,694,000 against $1,772,131,000 a year previously.

In the accompanying tabulation is shown financial data for the 23 American companies and two others, Creole operating in Venezuela, and Imperial of Canada, for the past five years.

FIVE YEAR FINANCIAL REVIEW OF U

	Net Income	Per Share of Com.	Net Working Capital	Net Capital Assets	Funded and/or Long Term Debt	No. of Pref. Shares	No. of Com. Shares	Surplus
Amerada Corp.								
1942	$5,271,885	$4.15	$5,542,107	$12,714,027	.....	.....	785,675	$7,461,287
1941	2,569,560	3.26	3,473,258	12,682,721	.....	.....	788,675	5,769,751
1940	1,775,734	2.25	3,124,396	12,016,406	.....	.....	788,675	4,774,541
1939	1,230,764	1.56	3,047,353	11,801,630	.....	.....	788,675	4,576,157
1938	1,634,486	2.07	3,680,800	11,591,429	.....	.....	788,675	4,922,742
Atlantic Refining Co.								
1942	6,800,002	2.33	53,403,548	158,643,694	$26,305,709	148,000	2,663,998	96,943,179
1941	14,346,229	5.16	44,036,326	161,670,211	25,024,849	148,000	2,663,998	92,643,137
1940	6,217,453	2.11	45,152,518	145,997,524	25,124,849	148,000	2,663,999	80,620,957
1939	5,032,282	1.66	42,408,126	144,784,942	25,249,849	148,000	2,663,999	78,053,554
1938	4,310,913	1.40	40,723,724	142,172,139	25,406,849	148,000	2,663,999	73,270,967
Barnsdall Oil Co.								
1942	2,801,846	1.26	3,752,756	14,139,303	.....	.....	2,223,579	7,109,812
1941	(B) 5,026,202	2.25	2,928,159	12,897,743	3,140,000	.....	2,231,879	5,657,951
1940	2,193,471	.97	4,031,723	13,106,604	7,562,757	.....	2,251,017	1,926,084
1939	1,720,292	.76	4,534,676	11,071,041	7,575,979	.....	2,258,779	4,999,629
1938	2,837,894	1.26	2,884,341	11,416,400	5,000,000	.....	2,250,344	5,947,243
Consolidated Oil Corp.								
1942	18,060,598	1.42	101,393,765	216,238,439	92,395,928	.....	12,651,405	193,038,459
1941	16,472,494	1.25	83,592,829	216,209,874	79,588,000	.....	13,128,953	181,692,426
1940	3,792,602	.28	91,144,403	194,838,625	69,030,627	.....	13,531,915	172,115,495
1939	7,540,880	.55	98,179,411	196,742,476	70,481,429	.....	13,751,726	183,590,985
1938	7,737,712	.55	97,874,488	201,583,988	72,179,196	.....	13,751,846	187,049,022
Continental Oil Corp.								
1942	14,924,698	3.19	27,954,923	82,045,727	5,859,055	.....	4,682,563	91,806,436
1941	15,398,082	3.29	17,646,983	82,010,052	8,714,875	.....	4,682,565	81,564,115
1940	4,317,658	.92	30,010,809	73,082,217	21,906,177	.....	4,682,568	70,848,410
1939	6,304,504	1.35	38,844,133	63,132,258	21,071,600	.....	4,682,572	71,213,345
1938	5,139,755	1.10	45,753,061	55,862,435	21,071,600	.....	4,682,581	69,591,015
Creole Petroleum Corp.								
1942	3,469,000	.50	4,360,149	75,539,403	.....	.....	6,974,356	45,720,611
1941	12,297,275	1.76	8,193,304	73,259,828	.....	.....	6,974,356	47,679,036
1940	6,834,170	.98	4,113,744	71,507,758	.....	.....	6,974,356	42,356,117
1939	9,590,306	1.37	7,463,866	68,869,647	.....	.....	6,974,356	42,496,303
1938	11,464,757	1.64	15,953,482	56,966,860	.....	.....	6,974,356	39,889,293
Gulf Oil Corp.								
1942	22,981,562	2.53	79,139,104	378,603,898	42,912,760	.....	9,076,202	137,829,905
1941	33,568,624	3.70	80,951,044	372,056,770	46,155,801	.....	9,076,202	128,462,646
1940	22,150,277	2.44	125,388,013	357,743,026	48,590,002	.....	9,076,202	107,609,862
1939	15,315,781	1.69	97,534,014	351,936,147	51,112,595	.....	9,076,202	111,929,542
1938	13,017,076	1.43	126,830,235	350,468,996	75,613,092	.....	9,076,202	115,308,601
Humble Oil & Refining Co.								
1942	29,243,303	3.25	56,022,566	336,571,341	52,370,414	.....	8,987,840	164,992,790
1941	35,356,558	3.93	45,823,214	325,080,832	42,014,167	.....	8,987,940	154,036,877
1940	28,107,503	3.13	41,137,524	313,065,476	42,417,737	.....	8,987,940	138,406,211
1939	29,950,288	3.33	40,298,938	304,322,126	42,721,438	.....	8,987,840	132,409,925
1938	35,800,354	3.98	37,440,543	295,440,883	42,640,805	.....	8,987,840	120,063,584
Imperial Oil, Ltd.								
1942	14,663,097	.54	60,583,509	44,826,797	.....	.....	26,965,078	54,021,208
1941	16,144,069	.60	56,767,380	43,103,735	.....	.....	26,965,078	53,383,418
1940	17,635,717	.65	45,061,925	41,243,450	.....	.....	26,965,078	50,721,888
1939	19,250,071	.72	43,959,297	41,125,802	.....	.....	26,965,078	49,936,345
1938	25,950,580	.96	60,013,498	40,253,368	.....	.....	26,965,078	61,202,540
Mid-Continent Petroleum Corp.								
1942	6,112,158	3.29	30,603,308	35,443,077	.....	.....	1,857,912	47,465,394
1941	4,803,036	2.62	25,110,651	30,035,163	.....	.....	1,857,912	44,893,313
1940	2,967,394	1.60	21,549,569	37,074,524	.....	.....	1,857,912	42,027,669
1939	2,650,502	1.42	20,139,581	37,068,405	.....	.....	1,857,912	41,904,545
1938	1,043,791	.56	18,614,252	38,158,682	.....	.....	1,857,912	41,309,132
Ohio Oil Co.								
1942	12,308,953	1.74	22,779,178	80,310,995	12,500,000	57,046	6,563,377	31,015,260
1941	10,799,736	1.42	24,895,921	89,838,837	15,500,000	212,233	6,563,377	24,405,355
1940	8,733,164	1.02	31,772,031	88,050,956	14,000,000	339,337	6,563,377	19,772,774
1939	1,492,086	(A) 4.29	30,468,732	90,583,528	18,000,000	354,537	6,563,377	15,596,459
1938	4,582,964	.25	28,340,324	96,328,461	.....	354,537	6,563,377	10,231,596
Phillips Petroleum Co.								
1942	13,129,457	2.95	33,630,615	188,723,195	38,608,431	.....	4,492,980	52,739,178
1941	17,346,977	3.92	30,001,026	180,708,712	33,923,259	.....	4,449,052	48,507,824
1940	11,590,317	2.61	29,130,002	173,186,916	32,589,696	.....	4,449,052	41,081,214
1939	9,833,314	2.21	24,305,805	174,933,218	33,598,518	.....	4,449,052	38,389,001
1938	9,049,122	2.03	43,662,204	160,683,920	41,417,920	.....	4,449,052	37,453,790
Pure Oil Co.								
1942	13,761,826	2.47	30,915,653	126,026,907	3,174,175	725,431	3,982,031	71,853,146
1941	15,285,255	2.86	24,719,281	123,223,061	2,952,147	725,431	3,982,031	63,990,259
1940	8,718,057	1.21	22,700,307	115,237,430	3,478,686	725,431	3,982,031	54,604,294
1939	8,290,418	1.11	23,186,755	112,484,522	2,361,852	721,956	3,982,031	50,781,163
1938	5,412,903	.38	19,793,782	112,992,307	2,455,668	721,429	3,982,031	47,603,410

UNITED STATES OIL COMPANIES

	Net Income	Per Share of Com.	Net Working Capital	Net Capital Assets	Funded and/or Long Term Debt	No. of Pref. Shares	No. of Com. Shares	Surplus
Seaboard Oil Co.								
1942	$1,463,706	$1.18	$3,314,271	$7,620,841	$3,440,000	.....	1,234,252	$3,816,255
1941	1,257,367	1.02	2,118,383	4,546,182	.....	.....	1,229,083	3,146,415
1940	1,300,993	1.05	2,698,551	3,980,081	.....	.....	1,244,383	3,439,929
1939	1,746,464	1.40	2,306,744	3,988,415	.....	.....	1,244,383	3,496,862
1938	1,895,790	1.52	2,368,575	2,968,905	.....	.....	1,244,383	2,994,781
Shell Union Oil Corp.								
1942	16,860,007	1.28	95,774,423	199,551,494	104,278,000	.....	13,070,625	34,086,647
1941	17,334,214	1.32	84,067,926	228,904,879	108,961,000	.....	13,070,625	36,648,283
1940	15,654,678	1.05	95,975,920	227,769,292	85,000,000	331,225	13,070,625	34,797,441
1939	11,805,713	.76	87,762,089	261,105,471	85,000,000	341,100	13,070,625	16,872,684
1938	11,318,423	.70	84,619,113	262,819,975	82,427,000	341,100	13,070,625	17,661,533
Skelly Oil Co.								
1942	5,632,805	5.73	11,863,363	52,375,519	13,600,000	.....	981,348	35,164,513
1941	5,913,826	6.02	8,445,051	51,063,964	14,800,000	.....	981,348	30,758,394
1940	3,316,678	3.28	7,694,042	48,279,943	16,000,000	.....	981,348	26,316,591
1939	2,360,783	1.99	7,788,739	45,009,713	9,000,000	63,000	995,348	25,581,908
1938	2,650,055	2.27	7,588,908	45,455,396	9,026,681	64,500	995,348	24,588,248
Socony-Vacuum Oil Co., Inc.								
1942	30,808,397	.99	234,062,698	481,070,509	123,674,996	.....	31,178,223	170,669,689
1941	43,175,902	1.38	216,888,148	471,740,585	126,383,580	.....	31,708,452	155,449,853
1940	36,409,055	1.17	197,297,070	455,058,914	133,727,410	.....	31,708,452	178,320,612
1939	34,452,710	1.10	189,357,083	493,139,415	120,419,256	.....	31,708,452	232,514,577
1938	40,106,917	1.29	(R) 205,882,740	(R) 458,244,042	127,511,486	.....	31,707,991	213,664,902
Standard Oil Co. of California								
1942	30,558,547	2.35	93,310,560	470,851,310	40,000,000	.....	13,003,935	239,748,878
1941	29,909,421	2.30	103,755,136	455,881,836	40,000,000	.....	13,003,953	231,337,260
1940	22,487,586	1.73	88,553,262	445,593,600	25,000,000	.....	13,102,900	230,320,612
1939	17,882,505	1.36	88,095,224	446,839,002	25,000,000	.....	13,102,900	235,332,469
1938	28,875,053	2.20	64,489,533	449,350,905	.....	.....	13,102,900	236,967,035
Standard Oil Co. of Indiana								
1942	44,183,893	2.89	203,989,055	413,433,258	16,453,283	.....	15,284,892	348,050,454
1941	48,385,967	3.17	185,923,067	431,134,000	14,698,741	.....	15,284,935	319,452,179
1940	33,597,342	2.20	191,548,946	396,068,183	19,488,465	.....	15,271,982	294,114,662
1939	34,142,643	2.23	186,837,449	378,973,235	8,713,074	.....	15,272,014	277,710,485
1938	27,771,976	1.82	174,727,455	374,827,700	10,346,658	.....	15,272,020	280,850,326
Standard Oil Co. (N. J.)								
1942	83,361,920	3.06	495,667,607	1,104,036,333	248,072,906	.....	27,283,587	642,011,449
1941	140,572,419	5.15	500,275,556	1,040,832,931	194,512,825	.....	27,283,587	636,189,422
1940	123,886,346	4.54	485,854,976	1,078,223,509	187,553,785	.....	27,278,666	618,087,745
1939	89,128,756	3.26	466,607,198	1,121,061,376	190,638,179	.....	27,285,919	593,326,890
1938	76,053,170	2.86	489,684,138	1,172,251,955	192,850,838	.....	26,618,065	562,803,025
Standard Oil Co. of Ohio								
1942	5,649,880	6.68	26,286,564	57,335,786	23,151,743	120,000	756,265	34,437,272
1941	6,249,443	7.47	17,566,209	51,799,637	9,446,676	120,000	752,265	31,088,988
1940	6,209,008	7.44	13,259,188	47,677,770	5,314,681	120,000	753,740	27,285,388
1939	5,602,499	6.64	15,403,625	43,965,974	6,702,971	120,000	753,740	23,180,208
1938	1,964,605	1.81	13,719,806	42,644,255	6,929,358	120,000	753,700	19,327,778
Sun Oil Co.								
1942	8,671,050	2.91	50,339,826	99,510,033	29,025,154	93,197	2,838,929	18,263,495
1941	16,539,540	6.21	36,011,101	93,470,154	21,007,495	93,197	2,850,826	13,004,990
1940	7,960,068	3.03	22,552,302	93,278,795	18,066,869	100,000	2,434,840	15,958,344
1939	6,959,677	2.74	29,845,003	84,353,938	21,275,043	100,000	2,318,918	15,091,224
1938	3,085,119	1.07	31,085,619	79,192,729	21,386,250	100,000	2,315,960	11,182,964
The Texas Co.								
1942	35,060,001	3.32	174,619,189	368,886,617	106,000,000	.....	10,875,627	237,718,261
1941	51,874,681	4.77	148,797,057	366,505,822	111,801,380	.....	10,875,800	222,837,338
1940	31,547,062	2.90	124,231,025	365,456,993	111,834,697	.....	10,875,904	197,634,702
1939	32,886,807	3.02	136,423,045	354,847,254	102,521,409	.....	10,876,139	200,036,059
1938	23,139,030	2.13	113,780,180	339,074,007	62,809,727	.....	10,876,882	188,912,882
Tide Water Associated Oil Co.								
1942	10,663,930	1.32	49,561,629	134,115,502	33,436,400	500,000	6,375,364	42,890,964
1941	15,564,093	2.09	42,482,262	137,982,146	36,936,400	500,000	6,374,033	37,342,770
1940	9,519,083	1.14	39,973,976	132,143,846	38,200,000	500,000	6,372,676	33,148,237
1939	8,958,971	1.05	40,018,720	126,832,660	36,848,615	500,000	6,368,667	33,094,647
1938	10,427,273	1.28	40,361,831	126,130,786	38,386,548	500,000	6,373,253	30,462,068
Union Oil Co. of California								
1942	5,537,329	1.19	48,758,124	133,893,458	43,639,030	.....	4,666,270	24,249,828
1941	6,239,232	1.34	36,622,981	130,271,906	37,480,000	.....	4,666,270	23,840,595
1940	4,606,790	.99	44,936,369	120,260,932	37,958,500	.....	4,666,270	22,283,270
1939	5,846,241	1.25	48,690,877	116,536,861	38,018,500	.....	4,666,270	22,350,171
1938	6,862,758	1.47	39,408,084	115,792,578	18,018,500	.....	4,666,270	22,953,078

(A) On preferred stock.
(B) Including a non recurring profit of $2,515,996 from the sale of West Texas lands.
(R) Revised because of European War and non-availability of certain figures.

INCREASED PRODUCTION

Through Secondary Recovery

Revised Estimates Indicate that of 4,000,000,000 Barrels Recoverable by Secondary Means Only Smaller Part can be Produced at Present Price of Crude Oil.

By Paul D. Torrey

AT the time when the rate of discovery of oil has declined to an extent that has caused Federal and State authorities and the officials of various technical and trade associations and organizations to emphasize the necessity for intensified oil-finding, the proven secondary reserve of the United States occupies a place of particular importance. In 1942, the Standing Subcommittee on Secondary Recovery Methods of the Topical Committee on Production Practice of the Division of Production, American Petroleum Institute, estimated that there existed in the United States a physically recoverable secondary oil reserve of 3,369 million barrels. Subsequent investigations by several members of the Subcommittee have indicated that this is a conservative figure and more complete information now available shows a secondary reserve in excess of 4,000 million barrels, a volume of crude greater than the total past production of a number of the important oil states. This figure does not include a probable enormous secondary reserve existing in many of the older fields in the state of California, where primary recovery efficiency appears to have been quite low in comparison to fields producing from formations of similar geologic age in Louisiana and Texas. Inferior primary recovery efficiency is one good criterion of conditions favorable for the application of secondary recovery methods. Excellent primary recovery efficiency is indicative of poor secondary recovery possibilities because of a low residual oil content remaining in the reservoir after the primary production phase has passed.

In giving consideration to the availability of secondary oil reserves as an assistance to the war effort, it should be kept in mind that only about 40 percent of the presently estimated secondary reserve of the United States can be produced profitably under existing crude price schedules. The necessity for an increase in crude price to prevent the abandonment of literally thousands of stripper wells, to stimulate the rate of exploration for new fields, and to encourage the more intensive development of new fields producing from deep formations, has been emphasized time and again by the leading petroleum authorities of the nation. Further comment on this vital subject is not essential to the purpose of this paper except for the fact that a general increase in crude price would make possible the profitable development of secondary recovery operations in many thin sand and deep fields, some of which are now in various stages of abandonment.

There appears to be a decided lack of the availability of the secondary reserve. This reserve may be regarded as being just as proven as any estimation of the primary reserve. Also, it is significant that secondary recovery operations generally are so flexible that increased production of oil may be secured at a rate comparable to the development of production in a new field. Thus, the secondary reserve should be given the same consideration as the primary reserve, subject to the limitations of price, in the formulation of plans for providing for the extraordinary requirements for petroleum and its products brought about by the belligerent status of the United States.

It would be hazardous to predict the amount of oil that may be required for the winning of the war, but attention is called to the fact that the present known secondary reserve of the United States, if immediately available, is adequate to supply the current rate of consumption for a period of over three years. Obviously, it would be infeasible and impractical to produce the secondary reserve at such an extensive rate, but the hope may be expressed that by a combination of the primary and secondary reserves, the amount of recoverable oil existing in the United States at the end of hostilities will be equivalent to the now known primary reserve.

It should be pointed out that the known secondary oil reserve occurs in large part in the older fields whose productive boundaries have been established by drilling years ago. Consequently, in fields adapted to the application of secondary recovery methods, no costly exploration and leasing programs, and no wildcat drilling are required. With proper technical guidance, the risk involved in the development of secondary recovery projects is very low. Therefore, in areas where oil is needed in large quantity for the offensive against our enemies it is possible that the supply required can be made available generally in a much shorter time period than might be required for the discovery and development of new primary production. Furthermore, since the quality of crude occurring in fields adapted to secondary recovery methods may be determined in fields adapted to secondary recovery methods may be determined in advance of any intensive development, the refiner may have the choice of procuring a grade of oil which will conform to his manufacturing system and to the quality and type of products desired.

The continued reduction in the quantity of materials available to the petroleum industry cannot be overlooked by any one engaged in the drilling and completion of wells. Oil is needed abundantly and at strategic locations where the demand or the particular quality of the crude produced requires a greater allocation of the limited amount of materials now available. It is notable that many secondary recovery operations can be developed in large part by the utilization of existing production facilities. Old wells can be rehabilitated and surface machinery and equipment repaired. Because of the general shallow depth of the fields in which secondary methods presently can be applied profitably, new equipment needed may be of the lower grades of steel. Salvaged equipment from other properties and fields and second-hand materials usually can be employed successfully.

Thus, increased oil production may be secured with a minimum of new materials, thereby providing a partial accomplishment of the program for more oil with less steel. Mention also should be made of the apparent waste of materials involved in the drilling of many closely spaced inside locations in older fields when the same results in desired increase in production might be secured with practically no new drilling by the application of secondary recovery methods. In this connection it will be recognized that the maintenance of reservoir pressure will be found generally to be more feasible and certainly more economical than the restoration of reservoir pressure. Therefore, the possibilities for the artificial injection of gas or water, even into recently discovered reservoirs, should be given immediate consideration in fields where poor primary recovery efficiency may be indicated. The methods developed in secondary recovery operations over a long period of years for the injection of fluids into oil-bearing formations may prove to be valuable guides for this purpose.

Compressors used for the extraction of natural gasoline frequently can be converted at low cost for injection purposes. Many smaller installations use belt driven compressors, the motive power being obtained from the engine connected to a central power. Loop systems for the gathering and distribution of gas affords material savings in line pipe over radial systems and may be employed to advantage where there are no great variations in injection pressures. Meas-

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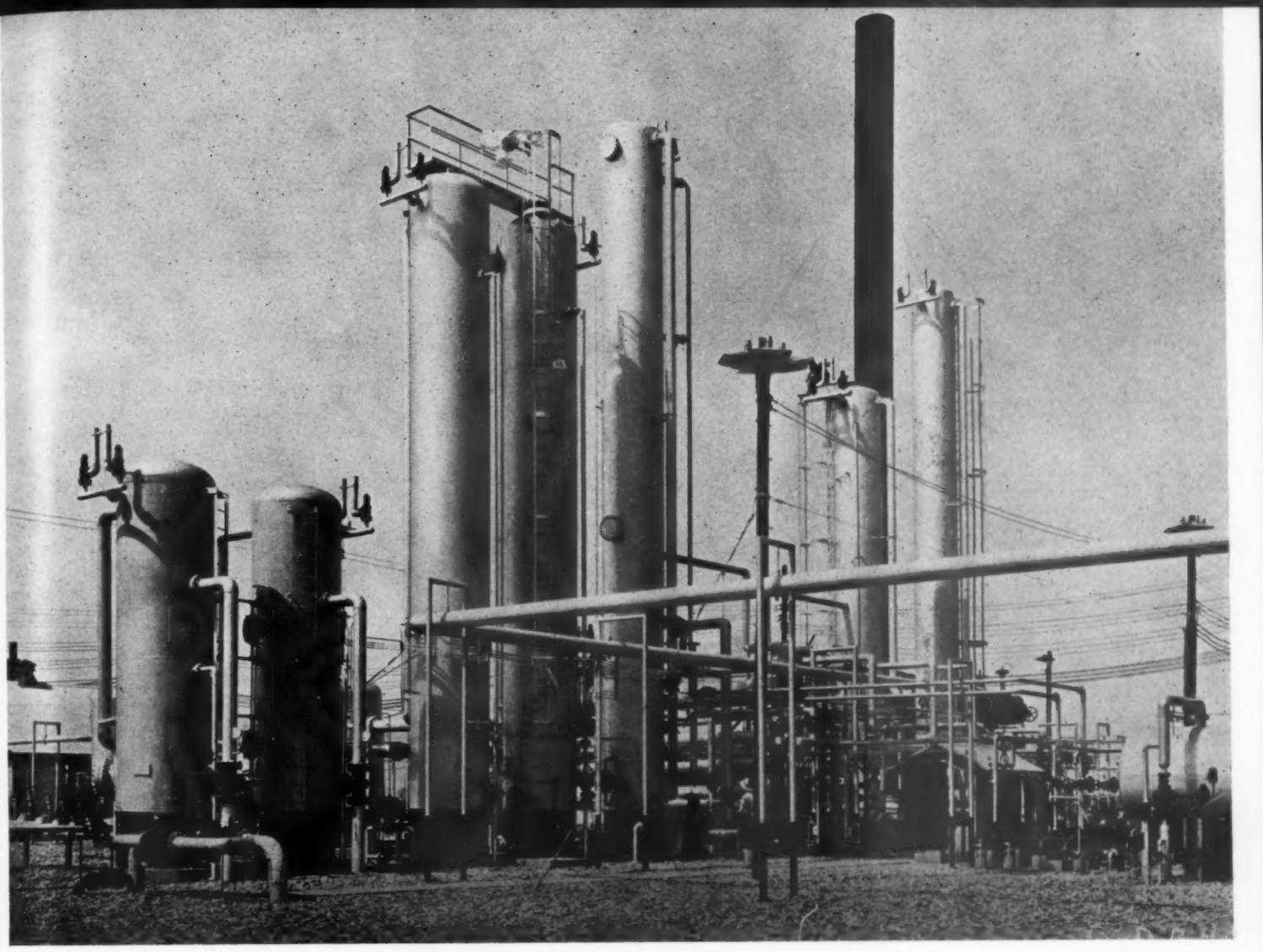
Presented before Division of Production, American Petroleum Institute, Dallas, Texas, April 30, 1943.



Continental Oil Company's crude oil stabilization and gasoline recovery plant where a complete pressure maintenance program has increased recovery from **3,650** *to* **200,000** *barrels per pound of decline in well pressure.*

ures taken to prevent corrosion of equipment will result in a low rate of replacement of equipment and will reduce the loss of production resulting from breakdowns. This is of particular importance where air or air-gas mixtures are employed as the injection medium. Protective coatings on pipe and simple dehydration system may serve to preserve the lines over an extended period and thus eliminate the necessity for frequent repairs and replacements, water-flooding operations require a source of water-supply, generally a water-treating plant, pumps, and a water distribution system. Usually a larger number of both injection and producing wells are required than are used commonly in gas repressuring projects. The greater development cost usually is compensated for by more complete and rapid recovery of oil, although some authorities have expressed the opinion that if gas injection projects were developed as extensively as the average water-flooding operation comparable results would be obtained.

The prevention of corrosion of equipment is one of the principal problems in the conservation of materials in water-flooding operations. This is of particular importance where salt water from underground sources is used as the injection medium. Another cause of corrosion is dissolved oxygen and carbon dioxide in the water. Some methods frequently employed for combatting corrosion are: the use of non-corrosive pipe and sucker rods, a costly method and one now almost impossible to employ because of the scarcity of alloy steels; the use of cement-lined pipe; the precipitation of an interior protective coating on the pipe by chemical means; decreasing the acidity of the water by chemical action; degassification of the water, and handling the water in a completely closed system so that no gases are absorbed from the air. These methods are used sometimes singly and in other operations in various combinations depending on the problems peculiar to the particular operation and to the scope of development.

A very promising, fairly recent development in water-flooding operations is the flowing of production instead of the pumping of wells. In this method, back-pressure is held on the oil wells and the pressure in the reservoir is allowed to build up, by the action of the water-injection pumps, to a point where the wells will flow. No surface pumping equipment for lifting the oil is required, resulting in a substantial saving in both surface and subsurface production equipment, and protected pipe for the control of corrosion may be used throughout the entire system because of the elimination of moving sucker rods and working barrels in the producing wells. Production costs are reduced.

Much has been written regarding the merits of unitization of oil fields during the primary production phase. The same benefits will prevail in secondary recovery operations, and in addition proper recognition can be given to the ownership of oil in place in the reservoir rather than when possessed and brought to the surface. By giving consideration to the reserve of residual oil underlying each property rather than to the surface area involved, the disparity in the quality of individual holdings which exists in almost every oil field, is given proper emphasis in the formulation of the unitization agreement, with the result that each operator will receive his equitable percentage of the recoverable residual oil content of the reservoir.

Above: The garage man turns bicycle repairer. With restrictions on all non-essential driving this garage attendant was only too glad to turn bicycle repairer when his assistance was needed.

Right: A familiar sight on London's streets. Horse vehicles are again back in service.

Britain Cuts Motoring to the Bone

By Alec H. Day

BRITAIN has long since settled down to a virtually carless period. Cars are a common sight on the road, but their total is only a tithe of that in evidence a year ago, and the cars still running are engaged in essential work and are mostly tied down by official restrictions to definite journeys.

Elimination of the basic motor spirit ration for private cars from July 1, 1942 seemed to bring war-time limitations on non-essential motoring to their logical conclusion. Motor spirit has since been allowed only in case of genuine need or for national service, but the authorities have not been content to leave it at that. They have tightened up restrictions and reduced allowances further.

Under the statistical blackout existing in the British petroleum industry, as in practically every other sphere, no background for motor spirit cuts can be furnished in figures. Increasing requirements of the fighting services and essential war work, intensification of the battle of the Atlantic, and need to conserve rubber normally used in tires, are among the main factors responsible. A stricter official view of the "austerity" desirable in the war-time life of the community may also have contributed to the decision to cut all private motoring to the bone.

Official statements have made it clear that new restrictions continually imposed do not arise from an actual shortage of petroleum products, but are designed to eliminate the risk of a shortage in the future.

Even the original allowances for private motorists at the outbreak of war were far from generous. Basic rations were insufficient to permit long journeys for pleasure, sufficing for a running of an average of only around 200 miles monthly. Many car owners found this barely enough for purely utility journeys, and had to cut out all recreation driving. From the first, therefore, motor spirit rationing meant a very definite limitation of normal activity, and involved considerable inconvenience for residents in remote districts relying on a car to keep them in touch with the nearest town.

Inconveniences were intensified by the gradual cutting down of basic rations and the paring of supplementary rations allowed for business and other necessities. Since the rationing scheme was abolished, those who could claim motor spirit for essential car work had had their allowances

further reduced, with special reductions on allocations for high-powered cars.

Simultaneously, inspection and supervision of cars on the road has been tightened up, and evasion or misuse punished more severely. In January a British motorist who had been given an allowance of spirit for a journey between far-distant towns — as British mileage goes — was fined for going 70 yards off his road to park his car while he attended a cinema performance.

The intention of the authorities since last July has been to take all non-essential cars off the road. This object has been accomplished for all practical purposes in spite of a small amount of evasion.

Although increasing restraints on the use of cars have meant new inconveniences, criticism of motor spirit restrictions has decreased as the grip of the control has tightened. There was something of an outcry when motor spirit rationing was first introduced in September 1939 on what was then thought by many to be an unduly severe scale. Public reactions to the final abolition of the basic ration and to subsequent control measures have presented a striking contrast. Hardly a complaint has been heard, although many British motorists have been laying up their cars altogether for the duration of the war.

This change of attitude can only be attributed to realization of the implications of total war, heightened by knowledge of the dangers encountered in transporting petroleum products to Britain.

Like the private car owners, commercial users of motor spirit have had to submit to increasingly severe restrictions. The allocations of a basic ration for commercial vehicles was discontinued early in 1942, supplementary rations for essential needs being now the only allowances.

Stores and other retail traders have to pool transport for deliveries of goods to customers and restrict deliveries to certain days of the week.

Motor spirit sales for commercial purposes were estimated before the war at about 50 percent of Britain's total civil consumption. With heavier cuts in private car allowances than in commercial transport, this percentage had increased to about 65 by the beginning of 1942.

Owing to the large number of private cars since withdrawn from the roads, it has already risen further, and commercial traffic now accounts for a predominant part of the nation's total civil consumption.

Moreover, Britain's consumption of normal commodities and manufactures is now severely limited by rationing and other measures, and the Government is absorbing an increasing part of the country's road transport. The proportion of total commercial spirit demand arising from normal trade must therefore be greatly reduced, and a continually increasing proportion must be used for carrying munitions and other war materials.

If the predominant needs of the fighting services are taken into account, and also the wide use for defense purposes of the cars remaining on the road, the volume of motor spirit devoted to normal uses as opposed to war needs must now be infinitesimal.

With a big reduction in the number of cars on the road, a corresponding decline will ultimately be witnessed in the Government's revenue from motor duties. That contingency has doubtless been foreseen by the treasury, which evidently considers that in sacrificing revenue for the sake of reducing motor spirit consumption it is choosing the lesser of two evils. The choice has probably been made easier by the decline in the relative importance of motor vehicle duties as sources of revenue. With the British Budget at its present total and general tax collections on an astronomic scale, the loss of a given amount of motor duty seems less important than it would have appeared a few years ago.

Actual collections of motor vehicles duty and total ordinary revenue for 1938-39 and 1941-42, with estimates for 1942-43, are shown in table I. Despite some defects, the rationing and other measures for control of motor spirit consumption have worked well. The system has proved flexible, enabling the desired limitation of consumption to be imposed at any given time, with a corresponding diversion of supplies to national purposes. But success has depended throughout on the remarkably efficient pooling system by which the oil companies have kept the nation supplied with petroleum products.

TABLE I

	1938-39	1941-42	1942-43 (Estimates)
Total ordinary revenue	£927,250,000	£2,074,057,000	£2,627,000,000
Motor vehicle duties	35,600,000	38,422,000	34,000,000
Motor vehicle duties percentage of ordinary revenue	3.8	1.8	1.3

TABLE II

New Price in force from:	Price excluding duty	Duty	Total price
Sept. 4, 1939	9d.	9d.	1s. 6d.
Oct. 17, 1939	11d.	9d.	1s. 8d.
Nov. 14, 1939	1s. 0½d.	9d.	1s. 9½d.
Dec. 23, 1939	1s. 1d.	9d.	1s. 10d.
May 22, 1940	1s. 2½d.	9d.	1s. 11½d.
Sept. 24, 1940	1s. 3½d.	9d.	2s. 0½d.
Feb. 17, 1942	1s. 4½d.	9d.	2s. 1½d.

Pooling came into operation at midnight on September 3, 1939 as a result of a request by the Government to the oil companies to prepare a scheme for the best possible distribution under emergency conditions. The request was for voluntary co-operation, and the scheme has remained voluntary, although it was prepared in close liaison with the government.

All the concerns entering the scheme agreed to place their complete storage and distributive facilities at the disposal of the Petroleum Board. This body is a war-time organization of the petroleum importing and distributing companies. Its business is to import, store and deliver petroleum products in the United Kingdom. The Board has nothing whatever to do with motor spirit rationing and has no part in current restrictions on consumption.

The task of the Board is the co-ordinating of the individual companies' facilities and organizing distribution on a combined basis. Virtually the whole industry, including the smaller independent distributors as well as the group formerly known as the "national" companies, came into the scheme, and all are represented on the Board.

Physical assets under the war-time control of the Board total approximately £23,000,000. Selling prices are fixed on a basis to give a return of 7½ percent on the value of the physical capital and on the working capital employed by the component companies, adjustment being necessarily made for any Lease-Lend oil supplied by the government to the Board for distribution.

Prices are naturally determined on the initiative of the Petroleum Board, but subject to government assent. When a change is necessary owing to fluctuations in the cost of laying down products in Britain, the Board makes proposals to the government, and changes its selling prices only when official sanction has been obtained.

Motor spirit quotations have shown a gradual rise since the outbreak of war. Table II is a record of the advance in the ex-service-station price for the "Pool" spirit which has been the only fuel available for petrol vehicles since September 1939.

In contrast with the complete official control applied to practically all commodities, petroleum products under the pooling system are under no direct government control of distribution. Pooling is operated entirely by the industry with the object of rationalizing war-time distribution, and it has fulfilled this function amazingly well.

Despite losses of cargoes, air-raid damage at ports and sometimes dislocation of internal transport, motor spirit and other petroleum products have always been available where and when they are wanted. It is generally recognized that the government did an excellent stroke of business for the nation when, instead of taking over the supply and distribution of these products, it left them to be handled by experienced distributors.

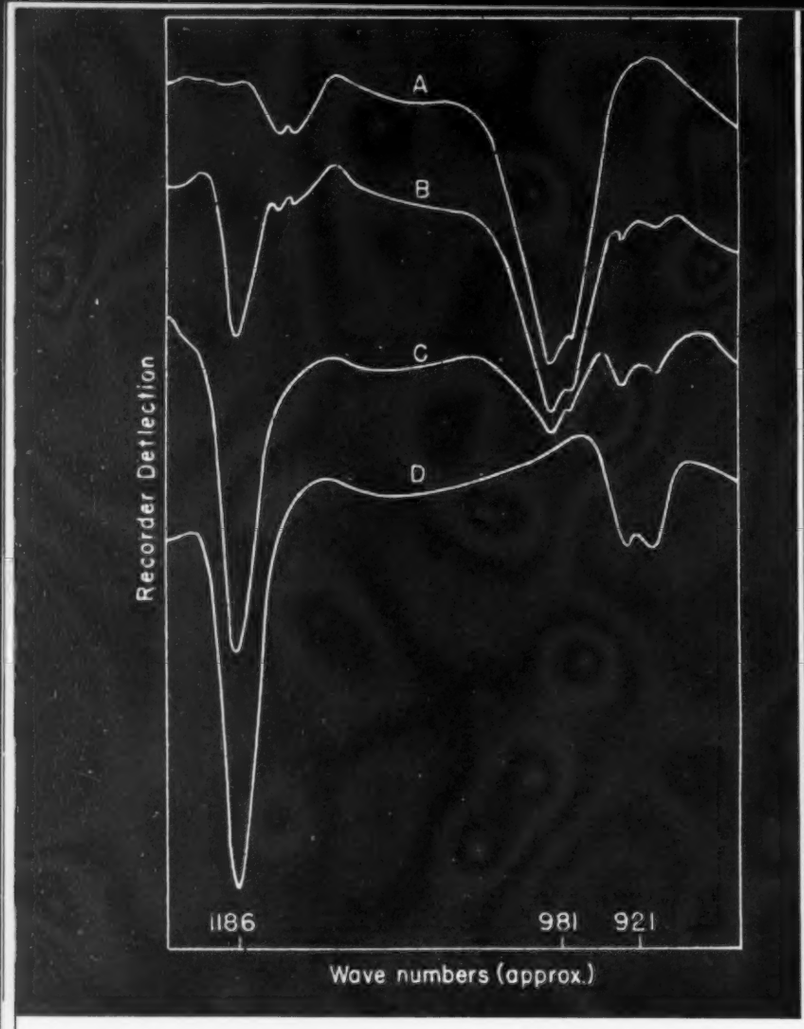


Figure 1: Spectra of four samples containing different proportions of the butane isomers. A — 99.4 percent n-butane; B — 30 percent isobutane; C — 70 percent isobutane; D — 99.7 percent isobutane.

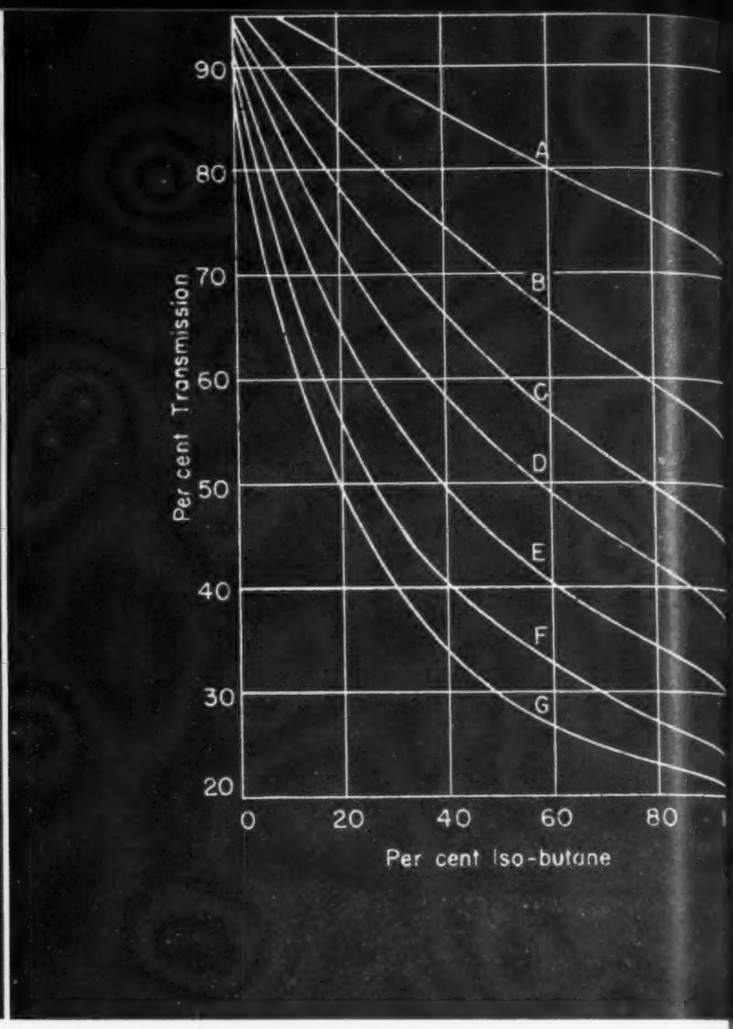


Figure 2: Percent transmission plotted against percent isobutane for various p sures (in mm. of hg) of sample in a 15 cm. absorption path. A—50 mm.; 100 mm.; C—150 mm.; D—200 mm.; E—275 mm.; F—375 mm.; G—475

SOME USES OF INFRA-RED SPECTROSCOPY FOR HYDROCARBON ANALYSIS

By R. Robert Brattain

SEVERAL papers on the uses of spectroscopy in hydrocarbon research have been published recently. Nielsen[1], before the American Association for the Advancement of Science, gave a general review of the uses of spectroscopy in the petroleum industry and Wright[2] has discussed more particularly the industrial uses of infra-red spectroscopy. These are only two of the more recent papers contributing to this field, which derives some of the fundamental ideas from the work of Coblentz[3] published in 1905. It seems advisable to avoid duplication, and consequently this paper will be restricted, as much as possible, to infra-red methods and instruments usable for routine analysis in actual plant operation.

Three different types of energy change within a molecule give rise to its spectrum. Changes in the electronic energy of a molecule cause either emission or absorption of radiation in the ultra-violet or visible regions. Examples of this, often used for analytical purposes, are the absorption bands of aromatic compounds in the 2400-2700Å range. Absorption in the ultra-violet region can be and is being used as a powerful analytical tool. However, parafins and mono-olefins do not have characteristic absorptions, caused by electronic energy changes, in a wave length region easily accessible. Practically all of their absorption is at shorter wave lengths than 2000Å and, consequently, they cannot be studied unless vacuum spectrographs, either prism or grating, are used.

Spectra caused by changes in the rotational energies of molecules appear in the far infra-red. This region, whose short wave length limit is usually taken as 30μ, is not used for analysis because the experimental technique is too difficult.

The spectral region which we are discussing today is referred to as the near infra-red and extends from 2μ to 30μ. The actual analyses discussed only make use of absorption between 3μ and 15μ but the methods and instruments described could be used to 30μ with slight modifications. Molecular spectra in this region are caused by changes in the vibrational energy. The particular wave lengths or frequencies of radiation which a molecule absorbs are determined by the masses of the atoms forming the molecule, the forces between the atoms, and their relative positions. For the simpler molecules it is thus possible to correlate completely the absorption bands in this region with the normal vibrations of the molecule considered as a dynamical system. Such calculations are most useful when infra-red spectra are being used for purposes other than analysis.

The above facts can be restated in a form which indicates more explicitly what may be expected when using near infra-red spectra as the basis of

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*Presented before the Technical Committee at the 17th annual meeting of the California Natural Gasoline Association at Los Angeles on November 6, 1942.

[1] "Application of Spectroscopy in the Petroleum Industry," J. R. Nielsen, Oil and Gas Jour., *40*, 34 (1942).

[2] "Application of Infra-red Spectroscopy to Industrial Research," N. Wright, Ind. and Eng. Chem. Anal. Ed., *13*, 1 (1941).

[3] "Investigations of Infra-red Spectra," W. W. Coblentz, Pub. 35, Carnegie Institution of Washington, 1905.

analysis. In general the spectra of two molecules will be different when any of the three following conditions exist:

1. The molecules contain different atoms (methane and chloromethane).
2. The molecules contain the same atoms but the bonds between them are different (butane and butylene).
3. The molecules contain the same atoms held together by the same forces but the atoms are in different relative positions (n-butane and isobutane).

A fact, which is essentially the inverse of the above conditions, also aids in predicting the usability of infra-red absorption as an analytical tool. This is that similar groups in different molecules will cause absorption at approximately the same wave lengths. Consequently, certain spectral positions are spoken of as characteristic of certain bonds. Vibrations which can be characterized as follows cause absorption approximately at the indicated wave lengths:

1. Stretching of a carbon-hydrogen bond $3.2 - 3.4\mu$
2. Stretching of a carbon-carbon single bond $8 - 12\mu$
3. Stretching of a carbon-carbon double bond $6 - 6.2\mu$
4. Stretching of a carbon-carbon triple bond $\sim 4.5\mu$
5. Stretching of a carbon-oxygen double bond $\sim 5.8\mu$
6. Stretching of an oxygen-hydrogen bond $2.7 - 2.9\mu$
7. Bending of a hydrogen-carbon-hydrogen bond angle $6.5 - 7.5\mu$
8. Stretching of a sulfur-hydrogen bond $\sim 3.85\mu$

From the above introduction it is seen that near infra-red spectra can be used on four types of analysis, namely:

1. Determination of the presence or absence of a particular chemical linkage in a compound of uncertain structure. Thus the existence of enol-keto tautomerism is often easily shown by the presence of both C — O and O — H absorption in the spectrum of the same molecule (e.g., acetylacetone $H_3C-\overset{\overset{O}{\|}}{C}-CH_2-\overset{\overset{O}{\|}}{C}-CH_3$ $\rightleftharpoons$ $H_3C-\overset{\overset{O}{|}}{\underset{\underset{H}{\diagdown}}{C}}=CH-\overset{\overset{O}{\|}}{C}-CH_3$).

2. Identification of the components of a fraction which has been isolated by distillation or other means. Avery[4] has illustrated this use in the case of a cyclopentane cut.

3. Quantitative determination of a small amount of impurity in a supposedly pure substance. This has been thoroughly discussed by Wright[2] using different halogenated hydrocarbons as examples. Unfortunately, some of the most elegant examples of this use of infra-red require a spectrograph of research rather than routine caliber.

4. The fourth type, routine quantitative analysis of mixtures of two or more components, and the instrument developed for this work will be discussed in detail below.

Any spectroscopic analytical procedure depends, from the simple standpoint, on finding a spectral position where only one of the components of a mixture absorbs strongly. However, the same absorption band may not serve to determine a particular component in two different mixtures. Consequently, the greatest simplicity and rapidity for routine analysis is achieved only when the analytical procedure is based on a detailed study of the specific mixture to be analyzed. This point is well illustrated by the analysis of butane mixtures which contain small amounts of propane and pentanes. If check analyses show that the amounts of propane and pentane remain below certain limits, a procedure which considers only the presence of the two butanes will serve to control an isomerization unit.

Regardless of the necessity of fitting the procedure to the mixture, certain general requirements can be stated for a spectroscopic analytical method which is to be used for routine analysis and plant control. The method should:

1. Be as rapid as is consistent with the precision required.
2. Yield the actual analysis from the experimental readings with a minimum of calculation.
3. Require only a simple procedure performed with a consistent and sturdy apparatus.

For a two component sample, the above general requirements are fulfilled most easily by a system requiring only the determination of the percent transmission at a single spectral position. With such a system, the largest change in percent transmission per unit change in isobutane content is achieved by choosing the proper values of the three variables: spectral position, spectral slit-width and specific absorption path. The optimum values of these variables may change with changing isobutane content of the samples under investigation. However, a rapid routine analytical procedure must handle all samples with a minimum of adjustments for sample composition.

The spectra between the wave numbers 1250 and 870 of four different mixtures of the butane isomers are shown in Figure 1. It is seen that large differences exist in this region between the spectra of these isomers.

The absorption band of isobutane at 1186 cm.$^{-1}$ was chosen as the spectral position. This band is freest from interference due to n-butane and is closer to the energy maximum of the source than the other bands shown in Figure 1. The absorption maximum of this band is used as the exact spectral position in the case of butane mixtures. However, in the case of another mixture a position on the side of an absorption band may give a larger change in percent transmission per unit change of the unknown component. This situation could arise if interfering absorption bands are present.

The spectral slit-width chosen for the analysis of isobutane in n-butane was about 65 cm.$^{-1}$. This

[4] "An Infra-Red Spectrometer for Industrial Use," W. H. Avery, Jour. Optical Soc. Am., *31*, 633 (1941).

* The discussion of two component mixtures was first presented before the American Physical Society, Pasadena, California, June, 1941. (Phys. Rev. *60*, 161, 1941) and was published by R. R. Brattain and O. Beeck, Jour. Appl. Physics, *13*, 699 (1942).

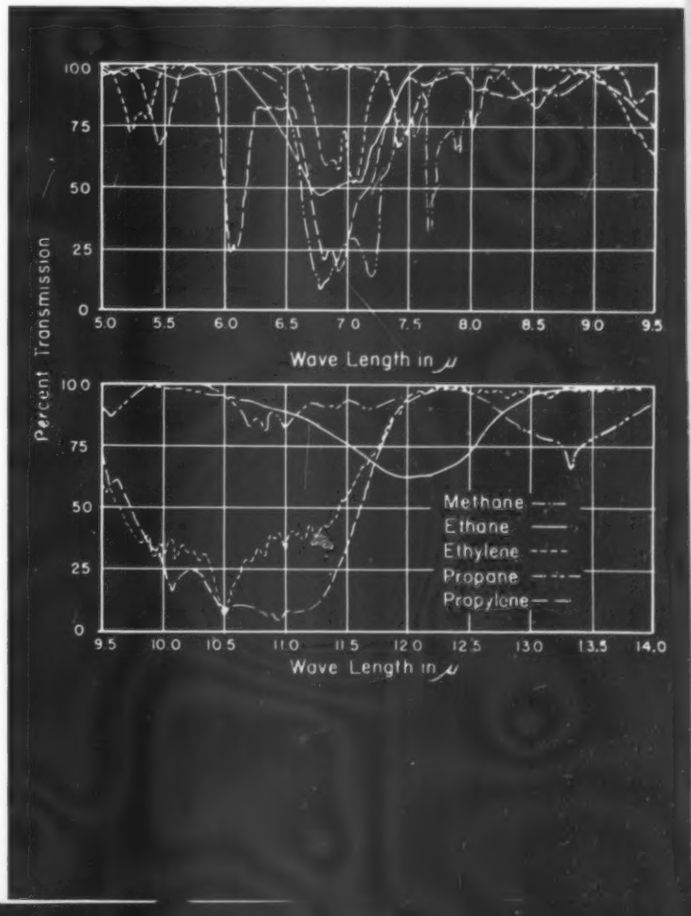


Figure 3: Composite spectra of methane, ethane, ethylene, propane and propylene.

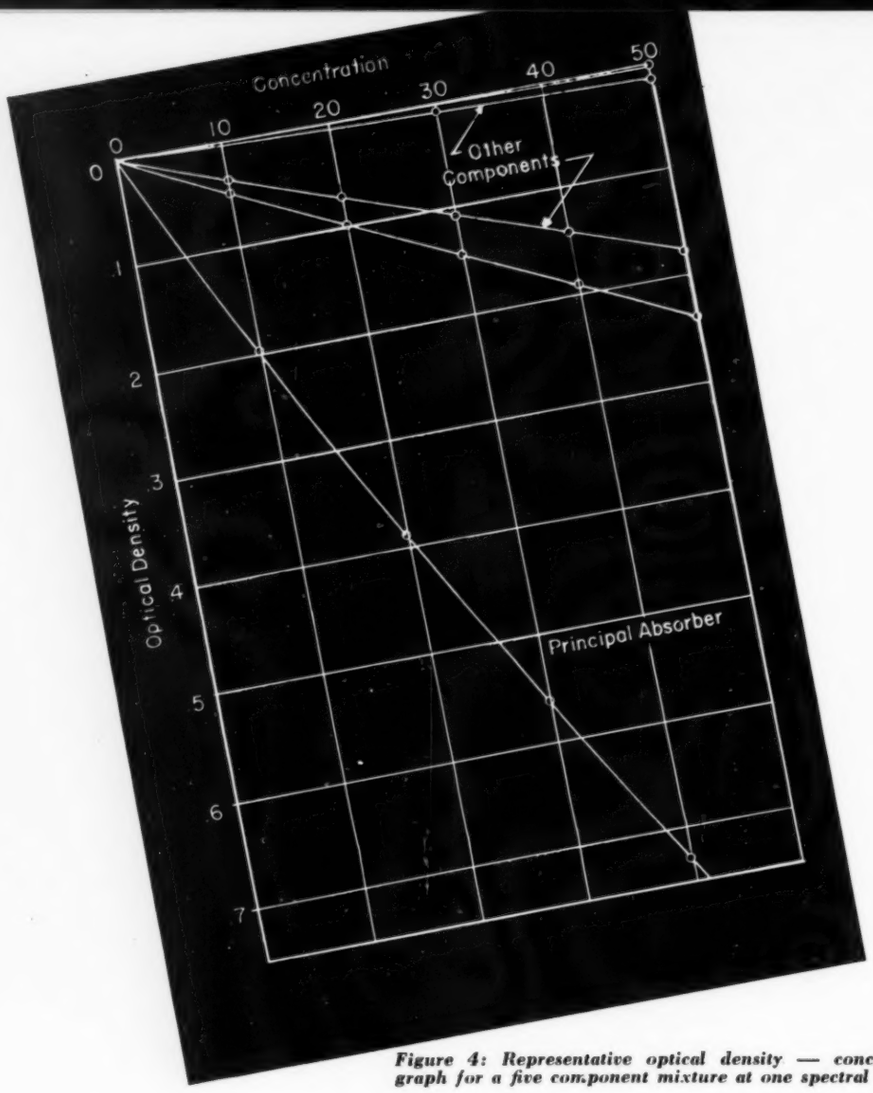


Figure 4: Representative optical density — concentration graph for a five component mixture at one spectral position.

value was selected to give the maximum energy strongly absorbed by isobutane in this spectral region.

Curves showing percent transmission plotted against percent isobutane for various gas pressures of the sample in a 15 cm. absorption cell are given in Figure 2. From these data, curve E (275 cm. pressure) was chosen as the most suitable over the entire 0 to 100 percent isobutane range and Curve C (150 mm. pressure) was chosen as the best if the sample contains more than 70 percent isobutane. Samples whose compositions were accurately known were used to obtain these curves.

To summarize, the routine infra-red analysis of n-butane-isobutane mixtures is made as follows:

The energy traversing the instrument and composed of the spectral interval from 1217 to 1153 cm.$^{-1}$, is read both with and without the sample in the light path. From these readings, the percentage of energy transmitted by the sample is calculated. The isobutane content (in percent) is then read from a calibration curve. The calibration curve is plotted from readings taken on synthetic samples whose compositions are accurately known.

This system was used, at the Shell Development Laboratories, to analyze 5,500 samples in 22 months. In addition, two special instruments using this analysis procedure are now being used for plant control work. The accuracy of these routine analyses is about ± 0.5 percent of the total sample. The accuracy is slightly better for samples low in isobutane and slightly worse if the isobutane content is above 85 percent. The time required for analysis is 20 minutes per sample. This figure includes time spent turning the instrument on and off, preparing the samples, calculating the results, periodically checking the method and making out analysis reports. It was arrived at by dividing the total time spent on these analyses by the total number (5,500) of samples analyzed.

The time is 15 minutes or less per sample if the number of analyses is sufficient to require 8 hours continuous work by an experienced operator. The average time per sample was increased to 20 minutes because six operators were trained within the 22 months with the spectrophotometer seldom in operation for more than 4 hours per day. One operator analyzed 38 samples in 6 hours, including calculations and other operations which were necessary but incidental to the actual analyses.

The results of some of the checks of this infra-red method of analyzing butane mixtures are presented in Table 1. Three different bases of comparison are given:

1. Synthetic mixtures whose compositions are accurately known.
2. Values obtained by low temperature distillation. The complete composition is given for these samples.
3. Duplicate spectroscopic values taken at least one day apart.

The accuracy of a low temperature distillation analysis is about ± 0.5 percent.

Propane, n-pentane, and isopentane are the impurities most likely to be present in a n-butane-isobutane sample. All of these compounds have some absorption in the region of the 1186 cm.$^{-1}$ isobutane absorption band. However, small quantities of these substances can be present without impairing the accuracy (0.5 percent) of the above simple analytical method. The maximum allowable amounts are 10 percent propane, 5 percent n-pentane, and 2.5 percent isopentane. Larger amounts of these impurities could be corrected for by readings at other wave lengths. This is possible on the routine spectrophotometer which will be described later.

None of the unsaturated four-carbon compounds, butenes and butadiene, have large enough absorption at 1186 mm.$^{-1}$ to cause small amounts of these compounds to interfere with this method of analyzing for isobutane.

The same system of analysis has been applied to mixtures of butene-1 and butene-2. The values of the three variables for this analysis are:

1. Spectral position — absorption maximum of the butene-1 band at 1841 cm.$^{-1}$.
2. Spectral slit-width — about 65 cm.$^{-1}$.
3. Specific absorption path — 400 mm. pressure of gas in a 15 cm. cell.

About 250 such samples have been analyzed by this infra-red method. The accuracy and time per sample are the same as for butane mixture.

Determination of the amount of a particular component in a complicated mixture is sometimes possible using only a reading of the absorption at one spectral position. This situation usually exists when the component of interest is markedly different in structure from the rest of the components, which are similar in structure. A possible example of this would be the determination of a ketone in a mixture of benzene homologues. However, it should be emphasized that such an analysis would have to be developed as a particular case.

A mixture of methane, ethane, ethylene, propane, and propylene will be used to illustrate the development of a procedure for the analysis of a multi-component mixture by infra-red absorption.

The time, involved in mixing standards and determining the curves to show the percentage of one component as a function of transmission at a particular position, is prohibitive when the percentages of the other components can vary arbitrarily. Hence the following semi-theoretical approach is used. For monochromatic radiation the transmission of a single component can be written:

$$(1) \qquad \frac{I}{I_0} = e^{-\alpha c x}$$

This expression is the familiar Beer's Law, where I_0 is the incident energy, I the transmitted energy, α the absorption coefficient, c the concentration and x the thickness of the absorbing layer. This expression can be put into the more familiar form:

$$(2) \qquad \log 10 \frac{I_0}{I} = \log 10 \frac{1}{T} = \delta c x = D$$

where δ is the extinction coefficient and D is the optical density. From these fundamental expressions it follows that, for monochromatic radiation, the transmission of a mixture is equal to the product of the transmissions of the components. Or, in the phraseology of equation (2) the optical density of a mixture is equal to the sum of the optical densities of the components. However, the transmission for a small wave length interval, and not monochromatic radiation, is actually measured. The transmission of a mixture then ceases to be a simple function of the transmissions of the components.

Nevertheless, under certain conditions, a simple relationship between the transmission of a mixture and the transmissions of the components can be used. These conditions are:

1. That it is possible to find a wave length interval, for each component, in which only this component absorbs strongly.

2. And that in this wave length interval only the extinction coefficient of this principal absorber changes rapidly.

Under these conditions, it is assumed that the transmission of a mixture can be considered equal to the product of the transmissions of the components, to a sufficient accuracy for analysis of the mixture, despite the fact that the transmissions of the components are not given by equation (1).

TABLE 1

Date Analyzed	% Isobutane by Infra-Red	% Isobutane Synthetic	% Isobutane Duplicate	Low Temperature Dist. % Isobutane	% n-Butane	% Propane	% Pentane
10/4/40	10.0	9.9					
10/9/40	45.8	45.6					
10/11/40	30.0	30.17					
10/11/40	45.9	45.6					
10/11/40	100.5	99.7					
6/11/41	20.1	19.86					
6/11/41	19.8	19.86					
6/11/41	29.8	30.17					
6/11/41	99.1	99.7					
7/14/41	20.0	20.12					
7/14/41	30.0	30.08					
7/14/41	40.0	40.08					
7/14/41	80.5	79.79					
10/14/41	43.5	43.9					
5/8/40	23.25			22.6	75.6	0.0	1.8
	12.0			11.2	88.4	0.0	0.4
	54.9			54.9	43.7	0.2	1.2
5/16/40	36.9			36.5	62.8	0.0	0.7
	16.0			16.3	83.3	0.0	0.4
	61.0			60.1	36.3	0.7	2.9
6/31/40	37.2			36.5	62.5	0.1	0.9
7/22/40	37.4			37.9	61.2	0.2	0.7
6/3/40	27.4		27.7				
6/10/40	48.4		48.6				
6/18/40	47.0		47.5				
6/11/40	22.2		21.8				

The significant parts of the spectra of methane, ethane, ethylene, propane, and propylene are shown superimposed in Figure 3. On the basis of this figure, the spectral positions at which the transmission of a mixture would be determined and the principal absorber at each point are:

5.22μ — ethylene
6.05μ — propylene

Figure 6: Routine infra-red spectrophotometer (cover removed).

7.68μ — methane
12.2 μ — ethane
13.34μ — propane

In preparing for actual analysis of such a mixture the data represented by such a set of curves as Figure 4 are determined for each one of the above spectral positions. Figure 4 is a plot of the optical density against concentration in a constant length cell for each of the pure components. The unit of concentration used in this calibration chart is the concentration of gas represented by 1 mm. pressure at 25 C. As in the above simple case of butane mixtures, the spectral slit-width and the pressure (concentration) can be chosen so as to attain maximum analytical accuracy at each absorption position. Within the limits of usable energy traversing the spectrophotometer, this generally means narrow slit-widths and low pressures.

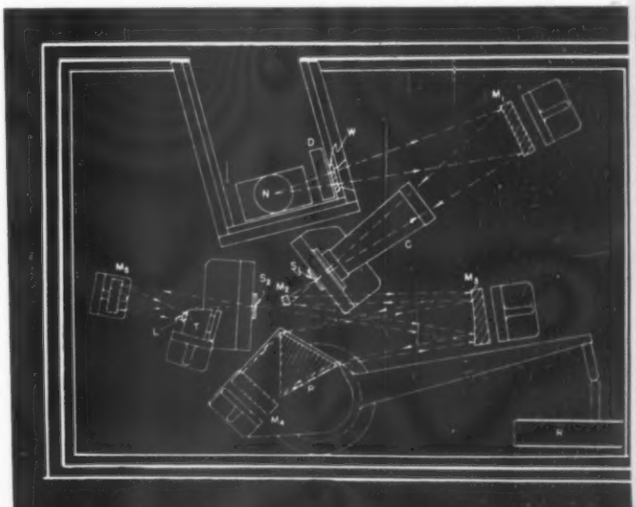


Figure 5: Light-path diagram of routine infra-red spectrophotometer.

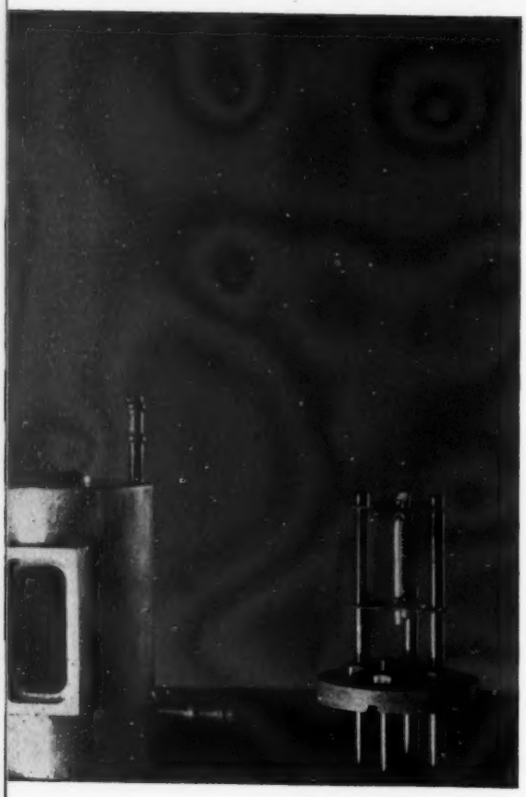


Figure 7: Nernst glower radiation source.

The actual analysis of such a five component mixture would then be accomplished by determining the optical density of the mixture at the five selected spectral positions using the predetermined slit-widths and pressures. The concentration of each component is then determined by solving equations of the form:

$$(3) \qquad D = d_1 + d_2 + d_3 + d_4 + d_5$$

This equation restates that the optical density of the mixture is equal to the sum of optical densities of the components. There is a similar equation for each spectral position—five in all. If the curves of optical density plotted against concentration (see Figure 4) are essentially straight lines, the concentrations of the components can be determined by simple linear equations derived from (3). If the above condition does not exist the concentrations can be determined by successive approximation. Although the latter system seems cumbersome, experience has shown that it can be completed in about 20 minutes for a five component sample. This multi-component analytical procedure should give an accuracy of about ± 1.0% using the routine infra-red spectrophotometer described below.

As briefly mentioned earlier, the possibility of using infra-red spectroscopy as an analytical tool has long been recognized. The principal reason that development has been slow until recently is the difficulty of experimental technique in the infra-red. Briefly these difficulties arise from the necessity of using:

1. Prisms of sodium chloride, potassium bromide or lithium fluoride.
2. Thermopiles, radiometers, or bolometers as energy measuring devices instead of photographic plates.

These difficulties have been overcome by gradual refinement over a period of years, until now it is possible to build an infra-red spectrophotometer which can be used for routine analysis in a plant control laboratory.

The instrument described here is the third model of an infra-red spectrophotometer which was designed particularly for routine analysis. The original development was carried on at the Shell Development Laboratories and this work is being used as the foundation of the improved instrument now manufactured by National Technical Laboratories of South Pasadena, California. It is through their courtesy that a spectrophotometer is available for inspection.

The light path and the arrangement of parts are shown in Figure 5. The radiation from the Nernst glower source, N, enters the spectrophotometer case through the rock salt window, W, and is focused by the spherical mirror M_1 at the first slit S_1. The sample cell, C, is attached to the frame of the first slit. The energy emerging from S_1 is reflected by the plane mirror M_2 onto the off-axis parabolic mirror M_3. M_3 is ground 14° off axis and has a diameter of 4 cm. and a focal length of 20 cm. Since part of M_3 is not filled by the beam from M_2 the aperture of the instrument is about F6. The parallel beam from M_3 traverses the 60° rock salt prism P twice, being returned almost on itself by the plane mirror M_4. The refracting faces of the prism are 4 cm. high and 6 cm. long. The dispersed beam returning from P is focused by M_3 onto the second slit, S_2, forming a spectrum in this plane. The radiation coming through S_2 is concentrated onto the receiving junctions of the vacuum thermopile, T, by the spherical mirror M_5 and the rock salt lens, L. The angular setting of the prism, and consequently the wave length of the radiation reaching the thermopile is controlled by the stop mechanism, R. This mechanism is a turret rotatable from outside the case, which carries hardened steel pins adjusted to give desired spectral positions.

A water cooled metal shutter and a diaphragm for regulating the energy entering the spectrophotometer are located at D. A shutter of lithium fluoride, for use at the longer wave lengths, and a magnesium oxide filter for eliminating visible radiation can be placed in the beam between W and M_1. The slits (S_1 is curved) are the bilateral parallelogram type and are both adjustable by the same control outside of the case. The entrance window, the prism, and the cell windows are protected from normal atmospheric water vapor by a thin coating of polystyrene. This is of use mainly during adjustment as the air inside the gas-tight, insulated steel cover is dried during operation. All parts are bolted and doweled to a heavy cast iron base-plate 22 x 16 inches. A view of the spectrophotometer is shown in Figure 6. The differential expansion mechanism, which rotates the parabolic mirror to compensate for the change in refractive index of the prism with temperature, is visible on the back of the holder for M_3.

The parts of the special Nernst glower source are shown in Figure 7. The water jacket (6cm. high) on the left is made from standard sizes of brass tubing. If the source is operated in a fire-restricted area, a rock salt window is sealed into the recess in the flange. Under these conditions, the screw in the top can be removed periodically to replenish the air (oxygen) inside the jacket, which is necessary for maximum life of the glower. The right-hand view shows the Nernst glower and its starting heater assembled. The glower and the heater are located, with respect to the stainless steel studs, by the two mica washers. The studs are spaced in the heat-resistant insulating disc so that they fit a standard four-pronged base. This disc for holding the studs also serves as the bottom end of the jacket. The assembled lamp on its base block is shown in the general view of a spectrophotometer given in Figure 6. All holes which affect the position of the Nernst glower with respect to the base block are jig drilled, allowing the source lamp to be replaced without readjusting any other parts of the spectrophotometer.

The ballast resistance, the transformer for the heater and a relay are in a separate box. The circuit is such that closing the switch to 110 volts a. c. impresses the proper voltage across both the heater and the Nernst glower. As soon as the glower reaches the temperature at which it conducts appreciable current the relay shuts off the heater.

Due to the high operating temperature certain precautions in the construction of the internal parts are necessary. All studs, spacers and nuts are made of stainless steel. The terminals are connected to the Nernst glower by the method described by Ebers and Nielsen[5] and the special heat-resistant wire, Kanthol A, is used for the heater.

The author wishes particularly to acknowledge his indebtedness to Dr. O. Beeck, who instigated and guides spectroscopic work at Shell Development Company, and to Dr. R. S. Rasmussen, the author's co-worker. Mr. H. H. Cary and Dr. A. O. Beckman have made major contributions to the design of the spectrophotometer and Dr. J. U. White of the Esso Laboratories and Dr. W. H. Avery of Shell Oil Company contributed helpful criticism and suggestions.

[5] E. S. Ebers and H. H. Nielsen, "A Method for Increasing the Life of Nernst Glowers," Rev. Sci. Inst., *11*, 429 (1940).

Foreign Oil Legion

TO INSURE that every employee of Tide Water Associated Oil Company now or hereafter on special leave of absence for active military service in the United States armed forces shall own War Savings Bonds, that company has adopted a policy whereby each such employee receives Series E War Savings Bonds of the aggregate face value at maturity of $150. William F. Humphrey, President of Tide Water is shown above presenting bonds to Lieutenant Lily Hutcheon, former secretary to the Company's Regional Counsel while Yeoman 1st Class Edward J. Moon, who was employed in the company's Credit Department prior to enlisting in the United States Navy and William F. Regan, Deputy Administrator, United States Treasury War Savings Staff, look on.

W. C. MACMILLAN (below), who has been appointed by President Dan Moran to be manager of Continental Oil Company's production and drilling department east of the Rocky Mountains, effective May 1. He succeeds J. G. Dyer, vice president, who resigned to become associated with a Denver oil production company. Mr. MacMillan has been with Continental for 15 years, and was formerly manager of the northern region of the land department.

ANNOUNCEMENT has recently been made of the appointment of Mr. A. E. Bedell as Chief Engineer of Graver Tank & Mfg. Co., Inc., in charge of all engineering and development covering all divisions of the company. Formerly associated with Max B. Miller & Co., Inc., and for 14 years in charge of engineering for that company, Mr. Bedell has had broad experience in the construction of refinery equipment, supplemented by previous experience in the chemical, power, sugar and general industrial fields.

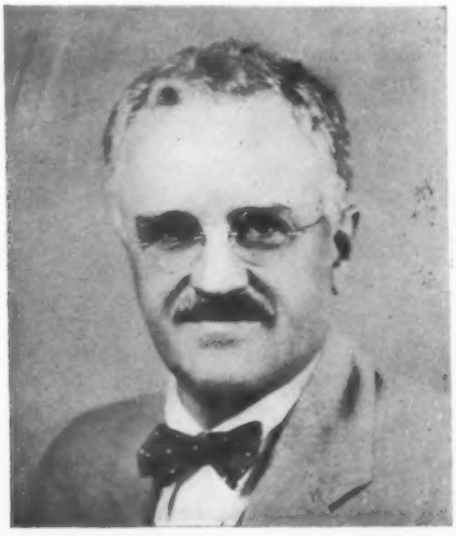
FRED F. HUBLER, Associated with Petroleum Rectifying Co., Tretolite Co., and the Dehydro Company as advertising manager, was formally inducted into the Army on May 10. Mr. Hubler has been assigned to the 940th Engineering Aviation Camouflage Battalion for preliminary training. Well known to the oil fraternity since his graduation from Stanford in 1931, Mr. Hubler's friends in the Mid-continent and California join in wishing him the best of luck.

JAMES W. VAIDEN (below), vice president of Skelly Oil Company in charge of manufacture and recently elected President of Natural Gasoline Association of America.

JOSEPH C. TREES, wildcat oil operator died on May 19, 1943 at Pittsburgh. Born in Trees Mills, Pennsylvania, Mr. Trees in his youth worked in a flour mill operated by his parents. He later drifted into school teaching and in his summer vacations worked for Standard Oil where he became friendly with M. L. Benedum, with whom he later formed a partnership, and thus began their fabulous career in wildcatting. Their success was out of all proportion to oil well wildcatting statistical experience, and some of the fields they helped develop were the big Ploesti fields in Rumania, fields in West Texas, Mexico, Colombia and other South American countries. Their West Texas discoveries were among the most significant in their partnership.

THE Army-Navy "E" production award was presented to the men and women of Ladish Drop Forge Co. on April 14, 1943. The short, business-like presentation was made in the plant at Cudahy, Wisc. Shown in the photo above, left to right are Lt. Col. Edward H. Bowman, U. S. Army Air Corps; Herman W. Ladish, Chairman of the Ladish Board of Directors; Otto Retzloff, employee representative and Captain D. D. Dupre, Commandant, Naval Officers Training Corps, Marquette University.

WALTER M. MILLER (below), vice president in charge of manufacturing for Continental Oil Company, Ponca City, Okla., who on May 4 was awarded an honorary doctor of engineering degree by the University of Tulsa. The award was granted in recognition of more than 30 years of service in the petroleum industry.



Right; Members of the Colombian Petroleum Institute shown while attending convention at El Centro.

P. E. LAKIN, vice president of the Marketing Division of the Shell Oil Company shown preparing the soil for his victory garden. He and approximately 12,000 other members of the Shell Victory Garden Club will participate in an extensive program, sponsored by the company, to promote the maintenance of victory gardens this spring and summer and the saving of as much food as possible for the next winter by the general public and Shell employees.

MEXICO, by picture and speech, was the feature of the regular monthly dinnner meeting of the Los Angeles Chapter of Nomads held in Los Angeles on May 12, 1943. After a short business meeting motion pictures dealing with places of interest throughout Mexico were presented by Walter Wells. The speaker of the evening was Hon. Carlos Grimm, Vice-Consul of Mexico who spoke on the attitude of Mexico during the war. The guests included C. A. Lilly of California Arabian Standard Oil Co. from Saudi Arabia; J. C. Russell of Y.P.F. of Bolivia from Bolivia; Harry M. Heath of the Texas Company from Caracas, Venezuela; Dave Dimitt of the International Petroleum Co. from Ecuador; J. A. Pryde of Shell of Colombia from Colombia; E. A. Brown and B. Beck of Caribbean Petroleum from Venezuela.

DR. PAUL D. FOOTE, executive vice president of the Gulf Oil Corporation's research and development organization, has been elected a member of the National Academy of Sciences. The Academy, which has a membership of 350 of the country's leading scientists, selects its members annually on a basis of recognition of scholarship and professional eminence.

THE Colombian Petroleum Institute held its first convention on March 27-29. The convention took place in El Centro by special invitation of Dr. P. F. Shannon, manager of the Tropical Oil Company at this location. The I.C.P. was founded a year ago with 13 charter members and now has a membership of 149. The present officers are Dr. Felix Mendoza, president; John O. Bower, vice president; H. B. Richardson and R. L. Morris, directors; Dr. Rafael Valencia Sampe, secretary and treasurer, and Paul H. LeFevre, auditor.

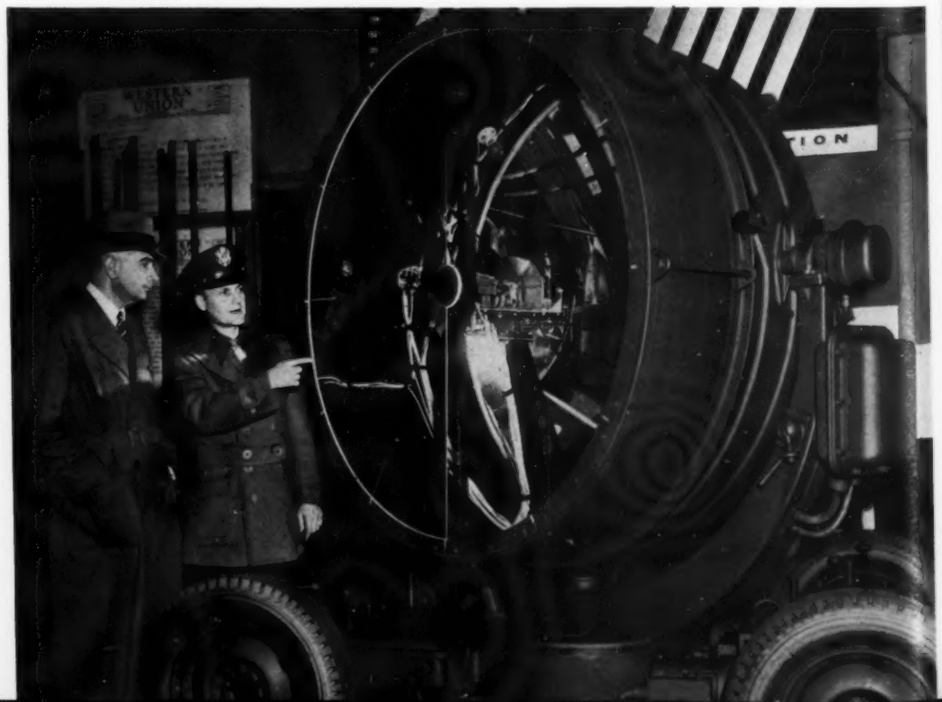
On Friday, March 26th, the members of the Institute arrived in Barranca Bermeja from many parts of Colombia and were transported to El Centro by special train. The following day the convention visited the offices, residences, gas plant, power plant, dehydration plant, Andian station and other installations of the Tropical Oil Company. At 2:00 p.m. a general meeting of the Institute was called in the Tropical Oil Company's International Club. The opening address was delivered by Dr. Shannon who welcomed the members of the Institute. Dr. Nestor Pineda, Honorary President of the Institute and Minister of Mines and Petroleum was presented by Dr. Felix Mendoza. In his address the Minister expressed the government's satisfaction with the organization of the Institute and indicated that the country should expect beneficial results from its activities.

Navy Wants Oil Men

THE Navy announces that it has a limited number of billets for outstanding men in the petroleum industry whose chemical engineering background combines experience in the design of refinery equipment and the manufacture of fuels and lubricants. A good knowledge of blending and refinery control is highly desirable. These men will be used to help solve one of the toughest supply problems of the war by aiding in the development of petroleum sources closer to the actual theatres of war operation. Known and potential deposits of oil exist in lands which have been or may presently be occupied by Allied forces. In such areas the Navy will employ the famous Seabees for reconstruction and rehabilitation of production and refining facilities. For experienced direction of these important jobs capable men in this field will be commissioned directly from civilian life.

Successful candidates will be given indoctrination and instruction to familiarize them with Navy bunker-fuel, Diesel-fuel, and gasoline requirements. They will then be assigned to duty with the Construction Battalion as planners and technical advisors in the refining of fuels for military use. Men with the necessary qualifications are requested to contact the Office of Naval Officer Procurement in their nearest major city.

DR. ALBERTO GAINZA PAZ, publisher of La Prensa in Buenos Aires, on a tour of American war plants as guest of the U. S. Government, is shown below inspecting one of the huge 800,000,000 candle-power searchlights being made by G. E. for the U. S. Army. Capt. F. W. Bailey is explaining the light, so powerful that a person 12 miles away is able to read a newspaper by its rays.



Crude oil goes to war

Today the available supply of crude oil is limited and so is the market for peacetime products

But the demand for war products that can be made from that crude oil is unlimited

Uncle Sam is the preferred customer He needs 100-octane gasoline, synthetic rubber and toluene in enormous volume

Don't you think refiners who can make those products—or their components—efficiently will have first call on crude if there isn't enough to go round?

It's wise and it's patriotic to get into war production as soon as you can

And it's wise to call on Universal refining specialists to help you They are helping to convert peacetime units to wartime operation right along

All Universal processes, as well as Universal experience and know how are at your service—at the service of every refiner

Call on U. O. P.

OIL IS AMMUNITION—USE IT WISELY CARE FOR YOUR CAR FOR YOUR COUNTRY

Universal Oil Products Co
Chicago, Illinois

Dubbs Cracking Process
Owner and Licensor

THE REFINERS INSTITUTE OF PETROLEUM TECHNOLOGY

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing with Technical and Economic Aspects of the Petroleum Industry—Edited by Dr. O. W. Willcox.

DRILLING

Direct-Current Rigs for Deep Drilling Operations —R. A. J. Dawson, before DIVISION OF PRODUCTION, AMERICAN PETROLEUM INSTITUTE, Houston Meeting, April, 1943.

This paper emphasizes the advantages of large, direct current, full-electric drilling to depths exceeding 11,000 feet in economical competition with other types of drilling machinery. The application of these rigs to depths beyond 11,000 feet is specified because it appears that portable internal combustion direct-drive drilling rigs have forecast the doom of steam rigs down to 5,000 feet, except in instances of predictable work favorable to steam. The depth range 5,000 to 11,000 feet is debatable ground where an accurate engineering analysis may decide the type of equipment required. At the present time fuel costs seem to be the most dominant factor over flexibility, portability, water cost, etc. In proven fields the gas-fired steam rig is still preferable, but in isolated areas steam is steadily giving way to power. Electric rigs can enter upon competition with other rigs in shallow areas only in certain instances, and their comparative cost prevents their adoption for shallow-to-medium depth wells.

From extended comparisons the author has reached the conclusion that, given sufficient design, prime mover horsepower, and electric power, direct current rigs can compete economically with steam to depths of 15,000 feet, provided that these rigs be given proper maintenance and well supervision. Thus far, four drilling rigs using direct current power are operating, and their performance has plainly indicated the many advantages of electric power for the deep wildcats of the future. The electrical and engineering characteristics of such rigs are extensively set forth in the paper.

The author insists that much of the bad reputation of electric rigs is due to misunderstanding between the so-called "practical men" and technicians of the drilling firms, the supply companies, and the electrical manufacturers. As a well known illustration, an electrical manufacturer designed an electrical setup for 10,000-foot drilling, only to have the supply company add a bigger drawworks and sell the rig for 12,000-foot competitive drilling. Before reaching 10,000 feet it was necessary to add a third prime mover engine, and because of unavoidable inflexibility due to hybrid design, deeper operations are conducted only with great difficulty. These expensive outfits must be tailor-made throughout to fit the job. In designing complicated and synchronized direct current rigs, one must be very sure to use only the best of available equipment, and the attempts of any one supply house or electrical manufacturer to engineer the assembly must be completely nullified.

No. 5 OF A SERIES TO HELP YOU KEEP CRACKING STILLS OPERATING AT PEAK EFFICIENCY

CARE OF SMALL TUBE CLEANERS

Tube cleaners, especially the smaller sizes, are subject to much unintentional abuse due to the fact that most of them are used in inaccessible places and under severe conditions. Small diameter motors necessarily depend on high speeds and close tolerances for their power. Although suitable steels are used in their manufacture, the combination of severe service and high speeds will cause excessive wear unless they are taken care of. Small parts worn even slightly cause rapid power loss. That is why we stress proper care of small diameter cleaners. Frequently, the deposit in which these cleaners operate contains corrosive substances. Particles of this deposit adhere to surfaces of motor and cutter head creating rust and causing corrosion. Immediately after using, they should be placed in a solvent for a short time and then thoroughly dried. Check blade and bearings for worn surfaces. Replace them and test motor. Then apply clean lubricating oil to all surfaces. Simple precautions such as liberal lubrication during operation, cleaning motor immediately after use and proper storage after checking prolong cleaner life . . . save time and excessive renewal or maintenance expense.

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Response of a Gulf Coast Drilling Mud to Chemicals, Temperature and Heat Treatment — George Faucher and Robert L. Whiting, in PETROLEUM TECHNOLOGY, March, 1943; Technical Publication No. 1589; 15 pages.

The drilling of deep wells is dependent upon the use of drilling mud, and problems frequently arise concerning the effects on mud of temperature, prolonged heating and aging. The use of chemicals to control the rheological properties of mud is a well-established practice. Salts of weak organic acids such as sodium tannate or gallate were used at first until the complex phosphates of sodium were found to be more efficient. Consequently, it seemed important to investigate the reaction of a mud to chemical treatment with phosphates, temperature, heat-treatment and aging, particularly since previous work in the laboratory at the University of Texas had provided the particle-size distribution and mineral composition of Hastings mud.

A typical drilling mud from the Hastings oil field, Brazoria County, Texas, containing only 8 percent (dry basis of material of colloidal dimensions, which is largely illite, was concentrated to a density of 10.2 lb. per gal. and used in this study. The effects of water dilution, treatment with complex polyphosphates, temperature and the time of heating upon the rheological properties of the mud were investigated. It was found that water plays an important part in chemical treatment and that sodium acid pyrophospate and sodium tripolyphosphate were made more efficient than other complex polyphosphates for chemical treatment. Muds treated with either of these chemicals manifested maximum reduction in viscosity and minimum filtration rates at low concentrations. Furthermore, mud treated to minimum viscosity with either of these two chemicals was virtually unaffected by heat-treatment.

Dilution of this mud with water lowered the viscosity and gel strength, and increased the filtration rate. However, minimum filtration rate when treated with a polyphosphate is obtained at the point of minimum viscosity.

Wildcat Drilling and Discovery Rates in 1942— Frederick H. Lahee, before AMERICAN ASSOCIATION PETROLEUM GEOLOGISTS, Fort Worth Meeting, April, 1943.

This paper reviews data on wildcat drilling for the eighth consecutive year. The pertinent statistics were assembled from 24 states. The total number of wildcat wells drilled in these states during 1942, as shown in this report, was 3,219; the footage drilled was 12,172,851. The corresponding figures for 1941 were 3,264 holes and 11,615,085 feet. The average depth for wildcat holes in all the states was 3,782 feet; in the southern states the average depth was 4,659 feet.

Taking the country as a whole, it is seen that out of the 3,219 holes that were drilled 493 became producers. These producers had a footage of 2,165,785 feet; 15.3 per cent of the holes, and 17.8 percent of the footage were successful. One producer foot was drilled for every 4.62 feet of dry hole, and one discovery well was drilled for every 5.14 dry holes. Considering the southern states separately, 16.3 percent of the holes drilled, and 24.5 percent of the footage drilled were successful; in this region one producer foot was drilled

for every 4.12 feet of dry hole and one discovery well for every five dry holes. The figures show that 18.3 percent of the holes drilled on technical advice became producers, as contrasted with 4.9 percent successful in the case of holes located without benefit of geophysics, geology, or technical indications. From this it is calculated that the wildcatter who avails himself of recognized sources of information has 3.7 times the better chance of finding oil than the one who dispenses with such aid.

In the year under review 566 successful wildcats were located on seismographic data; 52 others were located on a combination of seismographic and geologic advice.

OPERATION

Removal of Paraffin Accumulation in the University Field—Benjamin C. Craft and R. F. Nichols, before DIVISION OF PRODUCTION, AMERICAN PETROLEUM INSTITUTE, Houston Meeting, April, 1943.

The accumulation of paraffin within the tubing of producing wells constitutes a serious producing problem and greatly increases the lifting cost. Various devices are being used for scraping out the paraffin. The most popular one seems to be the ring cutter, also known as the circular cutter or biscuit cutter. In the University (Louisiana) field this cutter has the serious defect of being easily plugged with paraffin, is easily lifted up the hole by the well stream and dropped back, resulting in serious fishing jobs; two or three hours are required for scraping, and on weak wells chunks of paraffin would plug the choke and kill the well.

After some preliminary attempts the new knife illustrated in the figure was developed. The body consists of a ⅝-inch cold-rolled steel shaft which is drilled with 3/32-inch holes for the wires and tapped at right angles for Allen set screws. The scratchers were made from .092-inch diameter mild plow-steel wire, cut 2¼ inches long for 2½-inch tubing. The two semi-circular knives at the top are made of spring steel, are sharpened on top and bottom edges, and provide an open passage for the flow of cut paraffin and well fluid. For 2½-inch tubing the knives are 2¼ inches in diameter and may be either welded or bolted to the steel bar.

This tool eliminates all the undesirable features of the circular knife or biscuit cutter. The scratchers loosen and break the paraffin into small chunks from the wall of the tubing and any accumulations remaining are removed by the overlapping circular knives. The paraffin is then, even at low rates of flow, carried up the tubing, with no danger of plugging the choke. It is believed that the combination of knives and scratchers more effectively cleans the tubing than the circular cutter, which leaves a thin layer of packed paraffin on the inside of the tubing. Cutting time has been reduced more than 70 percent. It is believed that this equipment will prove economical in other fields where severe paraffin problems exist and it is suggested that the new scraper be tried on wells produced under the surface-controlled gas-lift system.

The Development and Control of Oil Reservoirs—S. E. Buckley and R. C. Craze, before DIVISION OF PRODUCTION, AMERICAN PETROLEUM INSTITUTE, Houston Meeting, April, 1943.

This paper is based on the booklet, entitled "Standards of Allocation of Oil Production," published in 1942 by the special study committee and legal advisory committee on Well Spacing and Allocation of Production set up by the American Petroleum Institute.

The author points to the fact that there is a well developed science of oil reservoir engineering, ruled by certain principles that are of a universal character, but which have to be applied in consonance with local circumstances. The oil operator has it impressed on him that oil fields are classified under three categories, according to the type of drive by which the oil moves to the surface under power supplied by the reservoir: (1) dissolved gas drive, (2) gas cap drive, and (3) water drive. It behooves the operator in a new field to find out, as soon as he can, to which of these types the field belongs, and then to operate the wells in conformity with that particular type. The most rational way to develop a new field is to adopt at first a wide spacing and learn the characteristics of the field from a few wells. With this information, which may be obtained from the first few wells, it will be possible to determine the proper spacing pattern, and much expense may be saved by avoiding unnecessary drilling. As the author observes, it is not possible to back up from close to wide spacing, but it is easy to fill in from wide spacing if closer drilling is seen to be advisable.

Of the three types of drive, the dissolved gas time is the least desirable and the one that demands the most skillful handling. In some cases the operator may convert this type into one of the more desirable types, which themselves provide many occasions for the exercise of common sense and operating skill. This short paper can be recommended as an excellent outline of the basic principles and applications of reservoir engineering which every producing oil man should have in mind.

NATURAL GAS

Normal Butane—R. C. Alden, Phillips Petroleum Co., before National Gasoline Association America, Dallas Meeting, April, 1943.

Under this title the author outlines a method whereby the natural gasoline manufacturer may

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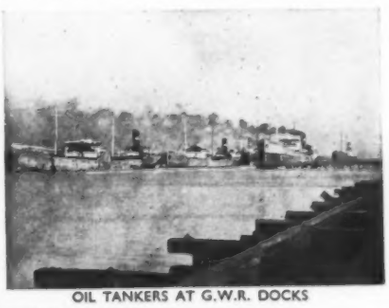

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contribute to the present demand for petroleum war products, and after the war be in a position to function as a manufacturer of motor fuel.

In the present situation, there is, or is likely to be, a shortage of isobutane. It is therefore necessary to focus attention on normal butane as a source from which additional isobutane may be obtained. It is further of significance that the large refinery consumption of C_4 hydrocarbons is raising a problem in motor-fuel volatility, which brings propane forward as a substitute for butane. These trends provide incentives for natural-gasoline manufacturers to increase C_4 extraction at their field plants, and it appears that butane is on the way of becoming as important as isobutane has already become.

At the moment, the most insistent demand on the natural-gasoline manufacturers is for more isobutane. To meet this demand the natural gasoline plant must have a "butane splitter," which will segregate the field isobutane from the normal butane. This "butane splitter" or deisobutanizer is a substantial part of the investment in butane isomerization plants, alkylation plants, and codimer plants. Thus any natural-gasoline manufacturer who is seriously considering a "butane splitter" for obtaining isobutane should also take into consideration amplifying his project to include at least facilities for butane isomerization, and perhaps alkylate or codimer production.

If in designing his plant the natural-gasoline manufacturer decides to go the whole way, he will provide for four distinct processes.

First will be the arrangement for segregating isobutane; the equipment will consist of the "butane splitter" and a depropanizer, and the products will be isobutane, n-butane, and propane and lighter. To this equipment is added an isomerization unit, which takes n-butane from the butane splitter and returns its product to the splitter; two additional products are isobutane and propane and lighter.

The third division of the complete equipment is an isobutane cracker for producing a supply of olefin. This cracker takes isobutane from the depropanizer and cracks it to a depth of 20-30 percent. The fourth and final division of the plant is a codimer unit of an alkylation unit. In the event that neither of these units is installed the products of the isobutane cracking unit will be of interest to refineries with alkylation or codimer facilities. In the case that a codimer unit or an alkylation unit is installed, the natural-gasoline plant itself produces alkylate or codimer. The key to this chain of processes is the isobutane cracker, a simple outfit that gives a yield of useful olefin amounting to 75 percent of the isobutane charged, together with considerable hydrogen.

Where, in such a complete plant, butane extraction has been raised above 90 percent, the blend of butane-free natural gasoline and alkylate should have a R.v.p. well under 10 lbs. and an unleaded octane number of about 80.

With addition of facilities for segregating normal and isopentane at hand, vapor pressure and octane characteristics could be controlled over a wide range, and either now or in post-war time the natural-gasoline plant may manufacture motor fuel.

Tepetate—Six Years Later—E. O. Bennett and F. B. Haverfield, before National Gas Association America, Dallas, April, 1943.

The Tepetate (Louisiana) plant of the Continental Oil Company has now been in operation for six years. Experience during this period shows what can be accomplished in the management of a high-pressure project under the control of a single operator; that is, when the field can be operated as a unit.

In the first place, all phases of operation are concentrated at a single location in the pool. Oil and gas production from high pressure wells is carried through single lines to high-pressure separators for each lease; these separators are all located at the central plant. Gas from the separators is metered and passed through high pressure absorbers for the removal of condensible products, and is then compressed and returned to the formation. The natural gasoline recovered from the absorbers is delivered by pipe line to the company's refinery at Lake Charles for use in the manufacture of alkylate for 100 octane number aviation gasoline. Oil from the plant stabilizer is also sent to the refinery.

One result from this arrangement has been the elimination of a low pressure field gathering system and lease tanks, and a great reduction in the labor required for conducting all field operations.

The outstanding result, which is attributed to the application of pressure-maintenance to the pool as a whole, is that the oil recovery to date is greater that the estimated ultimate recovery would have been had the field been produced in the conventional manner. In the beginning the estimated ultimate recovery by ordinary means was 11,000,000 bbl; production to date is nearly 12,000,000 bbl. The curve of production established by the record of the past six years indicates that final recovery will be around 17,000,000 or 18,000,000 bbl., or 6 to 7 million bbl. more than would ordinarily be obtained. And the whole amount of oil recoverable from this pool will be obtained by the equivalent of natural flow on account of the continuous return of compressed gas to the producing formation. Unlike the ordinary field which is produced without pressure maintenance there will be no old-age pumping stage for the Tepetate pool.

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Oceco Hatches are opened easily by pressing straight downward on the foot treadle (see view above) thus avoiding the danger and awkwardness of operating a vertical pedal. The hatches are self-closing, and are provided with a non-sparking composition ring set in the cover, that seats tightly against the narrow seating edge of the body, assuring *positive spark-proof gas-tight closure*—thus preventing any loss of volatiles through the hatch, and the resulting fire hazard. Oceco Hatches are furnished with steel plate flanges for welding or bolting to the tank roof — or threaded for pipe mounting. Prices, sizes, and complete description of standard, pressure type, stirrup-operated and other special designs sent on request. Write for Bulletin No. H-52.

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The pool is currently producing at the rate of 2,750 bbl. a day; this rate is set by the dictates of good production practice rather than by the market demand. To date somewhat more than 32 billion cubic feet of gas have been compressed and returned to the producing formation. As a consequence of this return of gas during the past six years, the formation pressure has declined from the original 3,600 lbs. only to 2,345 lbs., instead of the 1,400 lbs. that would have been reached under ordinary operations. It is figured that, since the pool will be produced to the end of its life by the energy that has been conserved in it, the saving in lifting costs by pumping will be more than sufficient to amortize the entire installation for compressing and returning gas to the producing formation. Besides that, the amount of gas already returned to the formation is the equivalent of 1,500,000 tons of average dry bituminous coal. This gas can be recovered for fuel at a far less expense than the cost of mining coal.

The Reciprocating Steam Pump in the Natural Gasoline Plant—H. P. Henderson, before California Natural Gasoline Association, April Meeting, 1943.

Conservative figures of a comparison of the steam consumption of the two types of pumps show that duplex pumps in the best of running conditions use from 10 percent to 30 percent more steam than simpler pumps of equivalent capacity and from 25 percent to 50 percent more when the duplex pumps are in only ordinarily fair working shape. This statement may possibly surprise many who have based their opinions on the too commonly accepted fact that all direct acting pumps are equally wasteful steam users.

In line with the above facts general conditions should determine the type of pump most suitable for a given service. If the pump is likely to be roughly handled, exposed to bad weather and subject to neglect—or if in the pump installation the steam, after being used in the pump, can all be profitably utilized for plant process purposes, etc., then the duplex pump will well fit the case.

If, on the other hand, conditions are such that maximum economy in operation is sought, together with high efficiency generally, then the simplex pump is the logical unit. It is nevertheless true that many pump installations are based not on facts as above presented, but on the engineers' preference for either one or the other type, due to long familiarity with duplex and simplex pumps, as the case may be.

In conclusion it should be noted that the steam pump is not an out of date machine but rather one that has a great many uses for which there is no substitute. For those who will spend the time to study the conditions of service, particularly with respect to intake conditions and apply and operate steam pumps carefully, there are rich rewards in plant economies.

CHEMISTRY

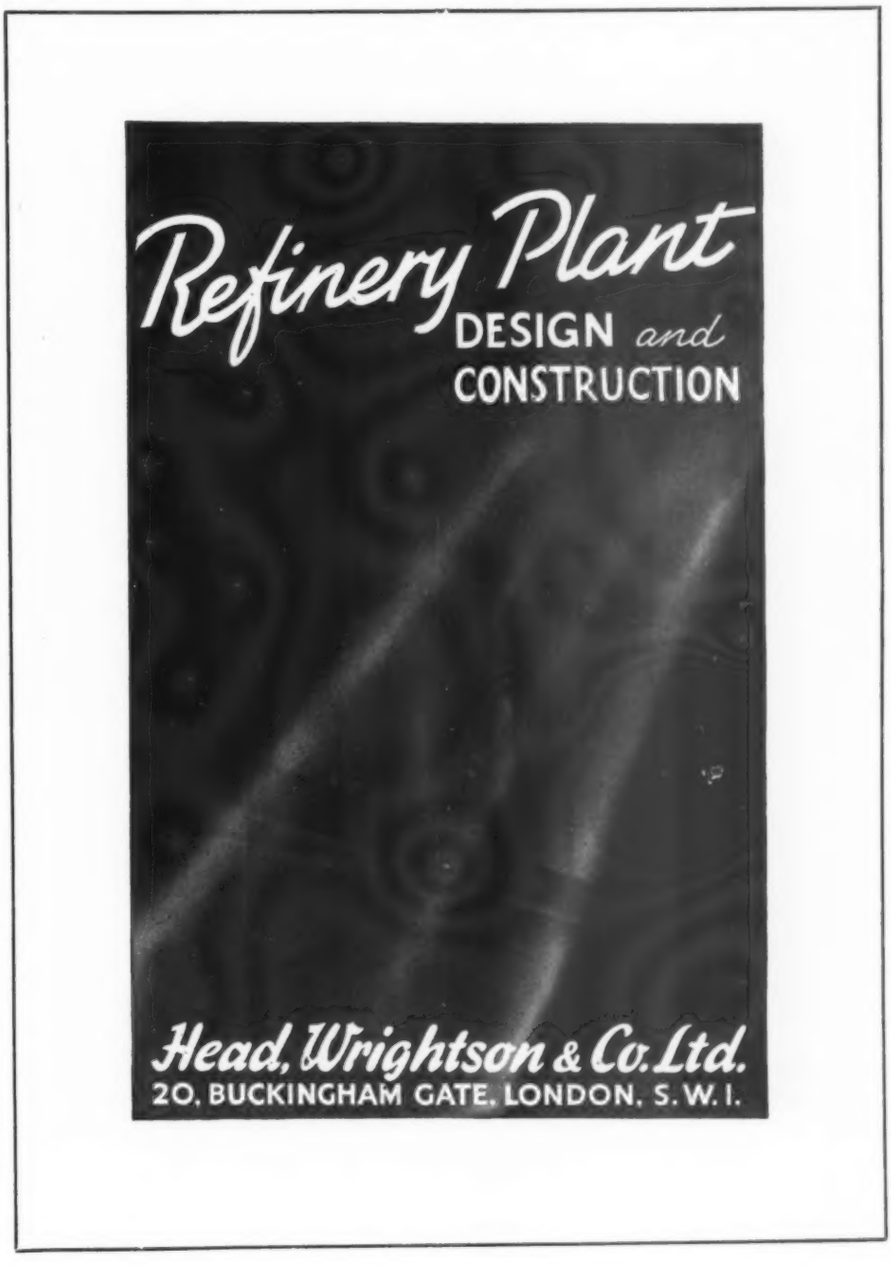
Thermal Value of Gasoline Method of Test—Harry Levin and Charles J. Schlagel, (The Texas Co., Beacon, N. Y.), before PETROLEUM DIVISION, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

A method is described for determining the calorific value of gasoline in an oxygen bomb calorimeter. It involves combustion of the sample contained in a sealed glass bulb wetted with lubricating oil of known calorific value. The technique secures prompt firing, clean burning, and reproducible results.

PHYSICS

Some Uses of Infrared Spectroscopy for Hydrocarbon Analysis—R. R. Brattain (Shell Development Co.) in PETROLEUM WORLD, Vol. 50 (1943), No. 2, pp. 46-56.

The author explains the use of an infrared spectrophotometer designed especially for routine analysis in petroleum laboratories. This instrument is now being manufactured by the National Technical Laboratories, South Pasadena, California, and is modeled from equipment originated at the Shell development laboratories.



The instrument functions on the principle that different hydrocarbons more strongly absorb radiations of certain wave lengths than others. The process of analysis, stated in general terms, consists in finding the wave length at which each component of the mixture absorbs strongly. A simple equation is set up:

$$D = d1 - d2 - d3 - d4 - d5$$

in which dl, etc., represent the optical densities of the individual components and D is the optical density of the mixture. Applied to the analysis of a gaseous mixture, methane, ethane, propane, ethene and propene could be determined by observing the spectral positions appropriate for each of the five components: 7.68, 12.2, 13.34, 5.22 and 6.06 mu., respectively. Linear equations giving the concentrations for the concentrations of the components can be derived from the general equation if the curves of optical density plotted against concentration are essentially straight lines. Where this condition is not met, successive approximations can be used; in this way, analysis of a mixture containing five components can be finished in about twenty minutes. With this multicomponent procedure the accuracy of the analysis is said to be within plus or minus one percent.

Determination of Butane-Isobutane Mixtures—Alfred W. Francis (Socony-Vacuum Oil Co., Inc., Paulsboro, N. J.), before PETROLEUM DIVISION, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

The percentage of isobutane in mixture with *n*-butane is determined by the critical solution temperature of the liquid hydrocarbon with *o*-nitrotoluene, which is a linear function of the composition. The C. S. T. with *n*-butane is 12.5°C. and with isobutane 32.8°C.

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FIBROTEX is non-abrasive and non-corrosive and can be kept in storage without deterioration. When mixed with mud, it can be held in reserve without losing its efficiency. FIBROTEX is furnished in paper-wrapped bales containing approximately 50 pounds. One bale will treat four barrels of mud and 50 barrels are generally sufficient for a single treatment. Should a seal be obtained before all the 50 barrels are used, the remainder may be stored for future use.

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REFINING

Catalytic Cracking by the Fluid Catalyst Process—E. V. Murphree, C. L. Brown, H. G. M. Fischer, E. J. Gohr, and W. J. Sweeney, before PETROLEUM DIVISION, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

The fluid catalyst process represents a new chemical engineering technique and has wide application to many industrial catalytic and noncatalytic operations. The present paper is concerned only with the application of this technique to catalytic cracking of petroleum fractions.

When oils are cracked, carbon is deposited on the catalyst, reducing its activity and making necessary its removal by burning with air. In the fluid catalyst cracking process the catalyst is handled as a fine powder, in such a way that it is kept in a fluidized condition at all times, in which form it may be handled substantially as a liquid. The catalyst is conveyed through the reactor by the oil vapor, after which it is separated in dust recovery equipment, with the product vapor flowing to conventional distillation equipment. The carbonized catalyst then flows down a standpipe in a high density condition, whereby its pressure is increased sufficiently to permit injection into a stream of air which carries it to the regenerator. In the latter the carbon is burned off, after which the catalyst is separated and the flue gas vented to the atmosphere. The regenerated catalyst then passes down a second standpipe and is injected into the oil vapor going to the reactor. The process is thus completely continuous as regards oil, air, and catalyst flow.

Information is available on production of motor gasoline from a variety of charge stocks. The motor gasoline has a clear octane number of 92-94 by the CFR Research method.

Operating conditions in the process may be adjusted to the production of war products such as high octane aviation fuel, butylenes, and toluene. Gasoline fractions from the operation may be used directly as aviation base or may be reprocessed in the fluid catalyst unit or hydrogenated. Aviation fuels produced by these methods have low alkylate requirements and when so blended, and after addition of lead tetraethyl, meet highest grade aviation fuel specifications.

Three commercial plants are now in operation and have given very satisfactory performance. A large number of additional commercial units are under construction.

Refining of High Melting-Point Waxes—Vance N. Jenkins, in OIL & GAS JOURNAL, Vol. 41 (1943), No. 46, p. 98.

In view of the high market value of high melting-point, crystalline type waxes available in crude waxes it is remarkable that no generally accepted method of refining has been developed to handle them. The author has now developed a process which is applicable to the deoiling of any crystalline-type wax; this process is installed at the Oleum refinery of Union Oil Co. of Calif., which is turning out 10 to 12 tons of fully refined waxes per day; the melting points range between 145°-150° F. and 160°-165° F. The idea underlying the development of this process originated in a conviction that, regardless of its melting point, a straight chain paraffin wax separates in an oil-free condition when it is crystallized from the oil with which it normally is associated.

The critical point in this process is the cooling

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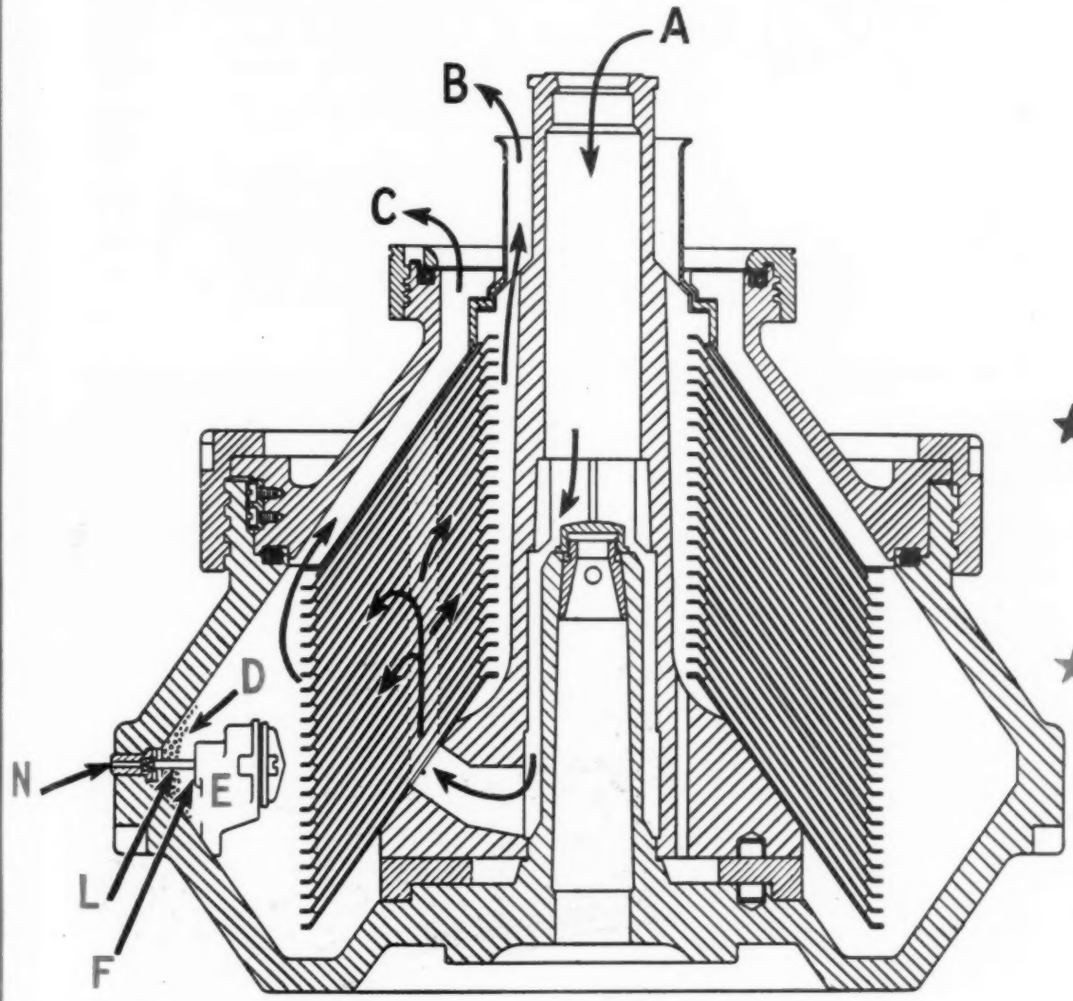

ROTOR OF CENTRIFUGE

★ A mixture of wool grease, water, and dirt enters the centrifuge rotor (frame and drive not shown) at A. Grease discharges at B, water at C. D indicates accumulated dirt particles.

★ E is the "brain." As long as a small flow of water can enter the "brain" chamber at F, it holds the valve L closed. When the dirt D builds up and blocks the entrance F, a change in hydrostatic pressure occurs in E. This opens the valve L. The dirt D then discharges through N due to the centrifugal force acting on it. The valve L will then close.

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operation during the crystallizing. The solidification of the waxes upon cooling to atmospheric temperature is prevented by continuous stirring; under this condition the wax crystals separating from the oil do not interlock to form a rigid structure, but form smooth semi-fluid slurries or stiff plastic mixtures of wax crystals in oil. The relative fluidity of these slurries varies with the viscosity and amount of oil. However, slurries having desired fluidities may be prepared from any crude wax by slight dilution with additional oil before or during the cooling operation; the nature of the diluting oil is of major importance. Essentially all of the high-melting-point waxes crystallize in an oil-free condition before the mixture reaches room temperature, mostly at 95°-100° F.

It was found that by use of an appropriate solvent under proper conditions these valuable high-melting-point components may be recovered by simple extraction or leaching of the properly prepared slurry. Methyl ethyl ketone is a satisfactory solvent for crude waxes containing low or medium viscosity-index oils: for the higher viscosity oils a suitable solvent is methyl ethyl ketone to which has been added about 10 percent of a light hydrocarbon boiling in the same range. Other details are extensively discussed in the paper.

The points that recommend this process are that an increased oil yield and a high-melting wax product are obtained at no increased cost over that of a single stage dewaxing process.

Azeotropy in the Refining of Petroleum—G. R. Lake, before DIVISION OF PETROLEUM CHEMISTRY, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

Distillation is one of the most important operations in petroleum refining, where numerous products have to be separated by fractionation. This art had its origin in the manufacture of spiritous liquors; the petroleum refiners, with much more complex mixtures to deal with, have constructed apparatus that make fine separations of closely similar materials. However, even with the modern practice of superfractionation, there are many mixtures that cannot be separated by ordinary distillation, it is sometimes possible to effect a separation by adding a third substance that has a physico chemical affinity for one of the components but not for the other one. In that case the added substance will associate itself with its affinity and will boil off with it at a lower temperature than would normally be required, leaving the other compound behind. This phenomenon is called azeotropism.

Azeotropism is of importance in petroleum refining where toluene has to be recovered from cracked products. The difficulty of obtaining toluene from such mixtures by ordinary distillation lies in the fact that the boiling point of toluene is within the boiling range of many light petroleum fractions. This was one of the difficulties that balked toluene production from petroleum during World War I. Since then, azeotrope formers have been found that will attach themselves to constituents of gasoline and carry them off as vapors, thus allowing the refiner to produce nitration-grade toluene for the manufacture of TNT.

By choosing other azeotrope formers it is possible to separate benzene from cracked petroleum products. Benzene, like toluene, is a highly important war hydrocarbon, as it is an essential raw material in the manufacture of snythetic rubber, aviation gasoline, and certain explosive.

Absorption and Stripping Design Method for Hydrocarbons—W. C. Edmister, before PETROLEUM DIVISION, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

Equations have been developed for making hydrocarbons absorption and stripping design calculations. Effective absorption (or stripping) factors, obtained by analytical equations from the terminal (top and bottom tray) conditions, are used in this method. Absorption and stripping efficiencies are computed by equations using these effective factors and taking into account the compositions of the wet gas and the lean oil in the case of absorption and rich oil and the stripping gas in the case of stripping.

The application of this method is outlined. For components appearing in both wet gas and lean oil it is frequently necessary to apply both the absorption and the stripping equations. A comparison of this method and other methods with plate-to-plate calculations indicates that this method is an accurate and rapid short cut.

The Mass Spectrometer and Its Application to Petroleum Refining—O. L. Roberts, H. W. Washburn, and L. N. Leum, before PETROLEUM DIVISION, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

The mass spectrometer as an analytical tool for use in petroleum refining operations is discussed. Examples of several types of mixtures which have to date been successfully analyzed by this new method are presented with comments regarding their accuracy and time required for analysis. The paper concludes with a brief discussion of several processes in which analytical data are useful in control, and in which the mass spectrometer method may prove valuable to the refiner.

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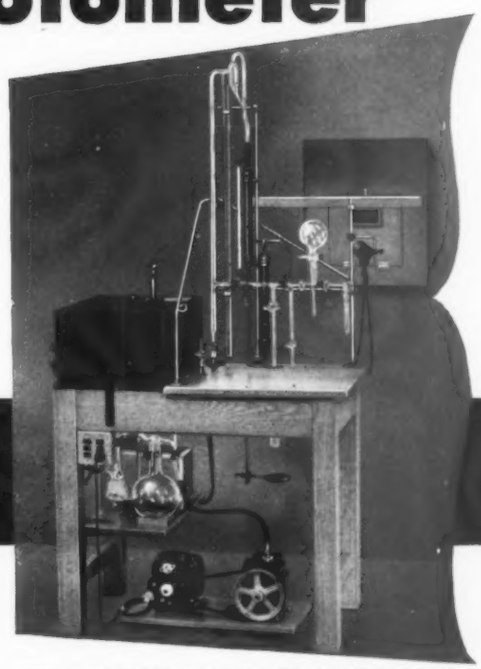

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Oxidation-Corrosion of Lubricating Oils—C. L. Pope and D. A. Hall (Eastman Kodak Company, Rochester, N. Y.), in AMERICAN SOCIETY TESTING MATERIALS BULLETIN, No. 121, March, 1943.

The authors describe an apparatus and procedure for an accelerated oxidation-corrosion test for lubricating oils, which is put to practical use by the industrial engineering department of the Eastman Kodak Company. It is reported that this test, in addition to being rapid, gives excellent correlation with service life.

The test consists in suspending test strips of metal in a 250-ml. sample of the oil in a vessel maintained at a constant temperature (100° C.). A current of moist oxygen is passed through the oil, which is constantly stirred. A reflex condenser returns most of the volatile oxidation products to the reaction. The test strips correspond to the metals used in service. In testing turbine oils the strips were wound with three turns of No. 18 copper wire; for Diesel engine oils; silver-cadinium or lead-copper assemblies were used. The samples were inspected at every 24 hours for color change and corrosion; a sample of the oil was tested for interfacial tension against water, and for neutralization number. After 96 hours the samples are tentatively classified into one of three groups: I, oils losing less than 5 dynes of interfacial tension; II, oils losing more than 5 dynes but retaining more than 15, and III, oils with less than 5 dynes of interfacial tension. Further testing may be continued for the estimated duration of the test.

Corrosion is graded as A, B, C, D; A being none and D very bad corrosion. Oxidation stability is judged primarily by the rate of drop in the interfacial tension, and by the rate of rise in neutralization number; secondarily, by the change in color, presence of sludge, and appearance of the test strips. Interfacial tension, which is a new oil may change from 40 or 50 down to 12 to 18, is a better single criterion than nuetralization number, which may change only from 0.10 in a new oil to 0.20. When the interfacial tension drops below about 18 it may be judged unsuited for further service.

In general, correlation of the results of this test, with actual practice is very informative. If the oxidation-corrosion test is run on an oil before it is put in service, and periodically while in use, the remaining useful life of the oil can be determined at any time. The tests have shown that it is possible under some conditions to prevent initial corrosion under some conditions of operation by adding a quantity of used oil to a new oil which was unable to prevent rusting. The two oils should be carefully selected and if possible of the same make.

This accelerated test brings out unmistakable differences in oils, though it may not indicate their best use, as regards film strengths under service conditions, which apparently must be learned by experience. It is pointed out that if a manufacturer of lubricants changes his refining technique or source of crude oil it is usually reflected by a different shape of the curves for interfacial tension and neutralization number; the user may suffer if he is not aware of the change, or if he does not know how to interpret the change in terms of actual use.

Lubrication of Steam Engine Cylinders with Emulsified Oil—R. Markl, in OIL UND KOHLE, 1942, p. 176.

The supply of lubricating oil is one of the most critical bottlenecks in the German war economy, and every effort must be made to use it to the best advantage. One of the places where a saving appears to be possible is in the cylinders of steam engines.

From a calculation of the amount of cylinder oil required for adequate lubrication of the cylinder, and a comparison of the calculated result with the amounts used in actual practice, the conclusion is evident that much too much of this precious material is being employed. The author ascribes this excessive use to the difficulty in distributing the oil uniformly, or so that it will easily get to the relative more accessible places in the mechanism. The trouble arises from the difficulty of breaking up the liquid oil into a sufficient number of very small globules, and this difficulty forces the use of more oil than is ideally necessary.

The author discusses the possibility of securing the necessary fine division of the cylinder engine oil by emulsifying it in water. This is a subject on which not much has been published. One of the first attempts to emulsify cylinder oil was to mix it

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with a little more than an equal volume of lime water and subject the mixture to prolonged agitation. The German railroad system adopted this procedure, but industrial establishments have been slow to follow suit. The presence of the lime is open to several objections, one of which is that it gets into the condensate boiler feed and is a source of incrustations. It is now possible to make better and more stable emulsified cylinder oils with Voltol. From recent extensive tests it has been found possible to lubricate steam engine cylinders in continuous operation with nearly the theoretical minimum amount oil, regardless of the fact that about 55 percent of the lubricant is water; that is to say, the usual consumption of cylinder oil is reduced more than half. Two engine tests that ran for 3,000 hours under varying conditions of load are cited. The report of these tests indicates that wear was less than usual, and there was less fouling with gummy crusts; the piston rings were still freely movable.

The effect of emulsification is to surround the minute globules of oil with a protecting film of water which is not immediately broken when the emulsion is introduced into the hot engine. That is, the emulsion is not destroyed until the oil has reached even the places most remote from the point of injection of the lubricant; thus the desired result is accomplished.

GENERAL

Proposed Methods and Estimated Costs of Mining Oil Shale at Rulison, Colorado—E. D. Gardner and Charles N. Bell, in BUREAU OF MINES INFORMATION CIRCULAR 7218.

For some years the Bureau of Mines has been operating an oil shale mine, with the object, among others, of obtaining cost data. In this region the oil shale occurs in the Green River formation, and is about 1350 feet thick. Different layers of this great shale deposit contain from less than 5 gallons of oil per ton up to 47.2 gals. The data reported in this circular relate to cost of mining the three richer sections, which are 20, 44, and 106 feet thick. For the 20-ft. bed it is estimated that the cost per ton of shale mined at the rate of 4,000 tons a day would be $0.96. To mine 5,000 tons a day from the 44-ft. bed (which would yield 4,000 bbl. of oil a day) would cost $0.712 per ton. From the 106-ft. bed at the rate of 10,000 tons a day (yielding 5380 bbl. of oil) would cost $0.538 per ton. Various mining methods can be used, such as the room-and-pillar method or the caving method; in some cases open pit mining may be applicable. The most favorable case is presented by the 44-ft. section; assuming a value of $1.00 a bbl. for the oil and a 95 percent extraction in the retorting process, the operation shows a profit of $0.088 per ton of shale mined.

Conservation of Steel in Oil Production and Transmission—V. J. Martzell, United Gas Pipe Line Co., Shreveport, before DIVISION OF PRODUCTION, AMERICAN PETROLEUM INSTITUTE, Houston Meeting, April, 1943.

This country's deposits of iron ore, like its deposits of petroleum, are limited in amount and are being produced at a rate that means early exhaustion. Authorities have figured that, barring new discoveries, there is enough oil to last about twenty years, after which recourse must be had to shale oil and synthetic petroleum, which are far more expensive. As to steel, it is now fairly certain that at present rates of consumption, there is enough high grade open pit iron ore to last only to 1950-seven years hence; after that, we must resort to underground mining and low grade ores, and iron ore will cost seven times what it now costs. It is therefore plain that conservation of steel is needed as urgently as conservation of petroleum.

It is from this angle that the author summons the petroleum industry to conservation of steel with an eye to the future as well as to the present emergency. He lists four lines along which the industry may and should practice conservation of steel and iron.

First is the use of new or old items already on hand as substitutes for others of similar make and construction that would have to be purchased new. This means that the planning of projects must be adapted to materials directly available. Just as much steel will be used as before, but none will be wasted because of obsolescence.

Next is the substitution of materials other than steel or iron, and there are very many places in the oil industry where this can be done with advantage. For instance, using concrete river weights instead of cast iron weights in the construction of pipe lines; coating such pipes with somastic coating (specific gravity 2.1) serves the same purpose, with the added advantage of protection to the pipe. Another example is the use of concrete counterweights on pumping units. "Millions and millions of tons of steel" are now needlessly used for this purpose.

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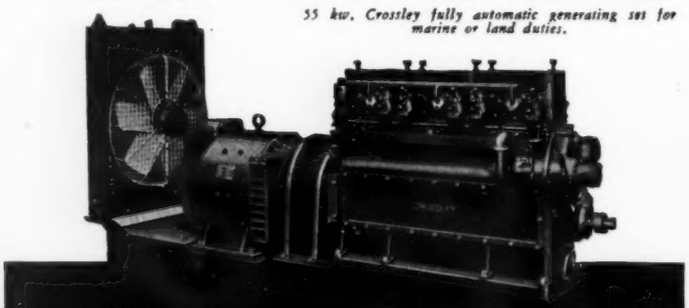

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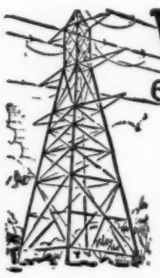

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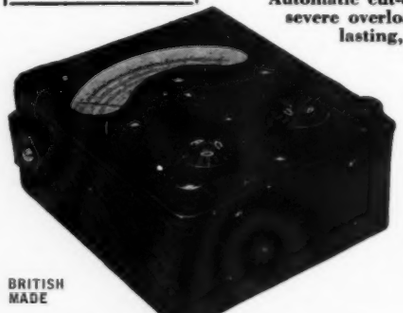

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2. **Keep the track tension correct, and the front idlers in alignment, so that wear will be evenly distributed.**
3. **Keep the rollers, idlers and diagonal brace bearings lubricated. This should be done more frequently if your tractor operates in mud or water.**
4. **Go over the nuts and bolts periodically to be sure they're tight. Look — and listen — for signs of wear.**

When tracks are worn to the point of needing repair, your "Caterpillar" dealer's excellent service facilities are available night and day, ready to:

1. **Turn track pins and bushings. In some cases this will actually double track life.**
2. **Build up worn rollers by welding.**
3. **Build up the rail side of worn track links.**
4. **Cut off worn or damaged sprocket rims and weld on new rims.**
5. **Weld new grousers on track shoes.**
6. **Switch rollers, especially if your equipment puts extra load on the front, rear or one side of the tractor.**

All these types of track service save metal —vital in today's war effort. Your "Caterpillar" dealer is pledged to keep your "Caterpillar" Diesel equipment working with the least possible expenditure of war-needed materials.

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The number of opportunities for such substitutions is almost infinite.

The third method of conservation is the protection and preservation of steel equipment now in use. The electrical protection engineers are daily improving their methods and equipment, and the foundries are improving the production of cast pipe which gives pipe lines a long expectancy of life. Another phase of this type of conservation is the protection of equipment not in use by periodical reconditioning, painting and lubrication.

The fourth method of steel conservation falls under the head of salvage. This means that if material can be repaired it must be repaired, because there is coming a time when the same material cannot be bought new. Nothing is to be consigned to scrap unless it is perfectly clear that it cannot be repaired and reused.

Importance of Natural Gasoline and Its Derivatives to the Synthetic Rubber and Aviation Gasoline Programs—Paul M. Raigorodsky and Frank H. Dotterweich, before WESTERN PETROLEUM REFINERS' ASSOCIATION, Wichita Meeting, November, 1942.

From the standpoint of the synthetic rubber program the most important constituent of natural gas is normal butane, of which the available supply appears to be adequate for all needs. For converting normal butane five major thermal cracking processes are available or under development: (A) low pressure, high temperature thermal cracking by the flue gas heating system; (B) low pressure, high temperature thermal cracking by the steam regenerative system; (C) thermal cracking using direct air injection; (D) thermal cracking with regenerative furnaces, and (E) tubular cracking at high temperatures. The main point of the first four consists in pre-heating the charge, raising it quickly to a high temperature in a specially designed reactor and quickly cooling the reaction products, from which the butadiene is separated. The regenerative furnace of the Wulff type for thermal cracking is receiving attention. This furnace as now designed is also used for manufacturing acetylene, and ethylene, which are also of importance in the manufacture of synthetic rubbers and other war products such as alcohol. The raw material may be pure butane or natural gasoline. Benzene is also a product of the Wulff furnace, and when combined with ethylene makes styrene, one of the constituents of Buna S.

A recent process is the Schoch electric process for obtaining acetylene from dry natural gas; synthetic rubbers can readily be made from acetylene. Natural gas also makes a further material contribution to the rubber program in the form of carbon black. The old channel process for producing carbon black is being replaced by furnace and cracking processes that give four times the yield, and besides are better suited for synthetic rubber than the channel-produced product.

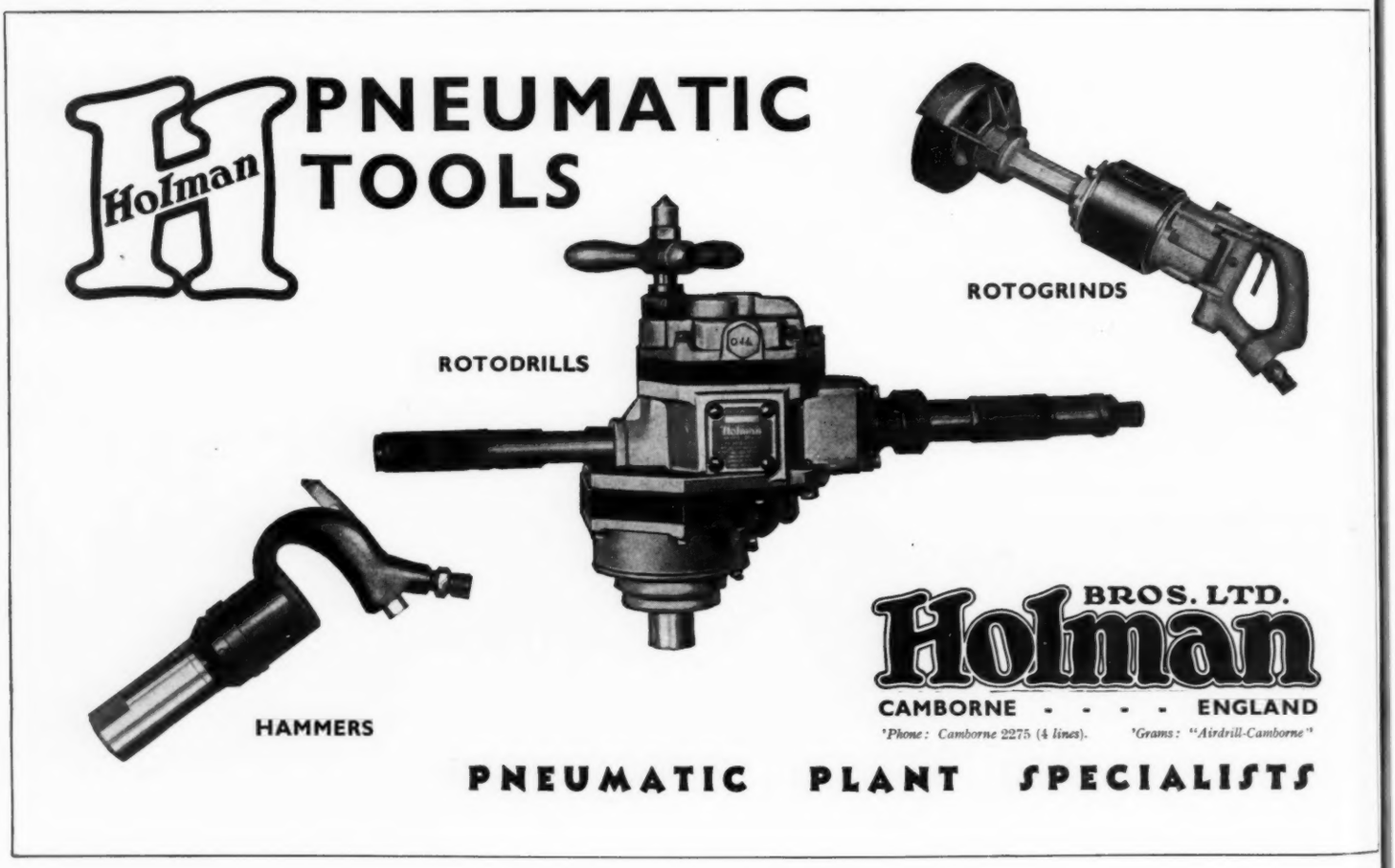
Aviation gasoline continues to maintain the greatest interest in refining circles. This invaluable product is now manufactured by many methods. Several gasoline plants in Louisiana and Texas are now making a naphtha fraction of about 70 gravity with 300° end-point that can be raised to 87 octane by TEL. This process eliminates a product that could not be disposed of under present conditions.

Natural gas furnishes the butane for isomerizing to isobutane, which is of the greatest importance for aviation gasoline. It also furnishes the raw material for neohexance, from which a 115 octane fuel can be produced. Isopropyl-benzene (cumene), another super-octane aviation fuel, can be made from the propane and ethane of natural gas. A special outlet for pentane is developing for its use by airplane manufacturers for breaking in new engines.

"Use of Materials in Secondary Recovery"—Paul D. Torrey, before Division of Production American Petroleum Institute, Houston Meeting, April, 1943.

Instead of the above title for this paper, the author might well have chosen to call it: "Present Importance of Secondary Recovery." The present importance of secondary recovery arises from the situation of the petroleum industry in relation to the war effort. The rate of consumption of crude oil is exceeding the rate of new discoveries; there has been a notable falling off in the number of new wells drilled, and fears have been expressed in authoritative quarters that the industry may fail to produce the more than 4,000,000 bbl. of crude oil that is called for by the 1943 program.

Clearly, there is a need for more exploratory work to find new pools, and more drilling to bring new wells into production. This need for more production raises the need for more of the materials and equipment required for a more intensive drilling campaign, and this, of course, involves an added strain on the none too plentiful resources of the WPB. But the wildcatters say that what they need most is a better price for crude oil to cover the higher costs of materials and labor and to provide an incentive to face the financial risks involved.



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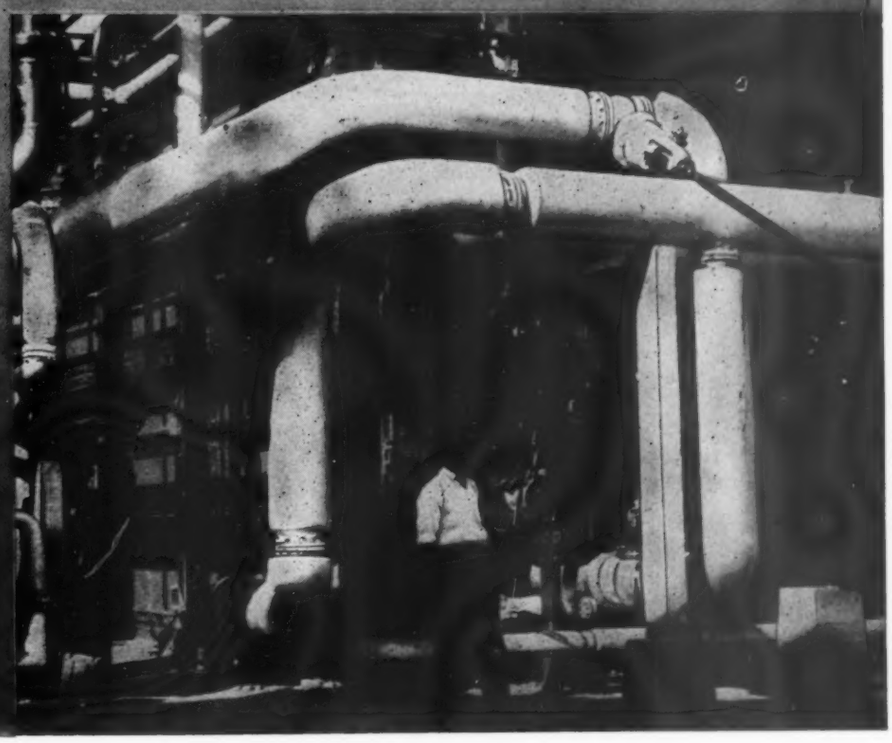


The author steps in to point out that in 1942 there existed in the United States a physically recoverable oil reserve of 3,369 million bbl. Recent investigations have shown that this is a conservative figure, and that it should be revised to above 4,000 million bbl., not counting a probable enormous secondary reserve existing in many of the older fields of California.

The present importance of this secondary reserve is that it represents oil that does not need to be discovered. Further, this oil occurs in old fields whose boundaries have been established by previous drilling. Consequently, no costly exploration and leasing program, and no wildcat drilling are required. With proper technical guidance the risk involved in the development of secondary recovery projects is very low. Therefore, where oil is needed in large amounts it may possibly be made available by secondary recovery methods in a much shorter time period than would be required for the discovery and development of new primary reserves.

Again, many secondary recovery operations can be developed with a minimum expense in money and materials. Old wells can be rehabilitated and existing surface equipment repaired. Additional equipment will consist mostly of compressors and line piping. Since secondary recovery is by pressure applied by air, or water, no expensive pumping installations may be needed.

The point is that here is one answer to the demand for more oil. However, the author does not neglect to point out that only about 40 percent of the presently estimated secondary oil reserve of the United States can be produced profitably under existing crude price schedules. This means that if more oil is wanted an adequate price will have to be paid. And a higher price is needed not only to stimulate secondary recovery, but also to halt the abandonment of literally thousands of stripper wells that are still contributing to the scant supply.

Properties of Mixtures of High Molecular Weight Hydrocarbons—R. W. Schiessler, D. G. Clarke, C. S. Rowland, C. H. Herr, and F. C. Whitmore (The Pennsylvania State College, State College, Pa.), before PETROLEUM DIVISION, AMERICAN CHEMICAL SOCIETY, Detroit Meeting, April, 1943.

The laws of mixtures governing viscosity and density have been studied for three binary systems (each containing three mixtures) of pure hydrocarbons of high molecular weight in the twenty-six to twenty-eight carbon atom range. In addition, three complex mixtures of pure heavy hydrocarbons have been prepared, the components having from twenty-five to thirty-two carbon atoms per molecule.

Complex mixture No. 1 contains twenty-two hydrocarbons, mixture No. 2 is made up of seventeen components, and mixture No. 3 is a blend of Nos. 1 and 2, therefore containing thirty-nine compounds in all. The properties reported for these multicomponent mixtures are: the kinematic viscosities at 68°F, densities and refractive indexes at 20°C, kinematic viscosity indexes, aniline points, and cloud and pour points. Method of predicting these constants (excepting cloud and pour points) from the properties of the pure hydrocarbons by use of mole-fraction, weight-fraction and volume-fraction data are compared.

The physical constants of these hydrocarbons pertaining to the mixture work are tabulated.

The research on these mixtures reveal the following:

The viscosity of a mixture may be predicted from the viscosities of the components with a fair degree of accuracy by assuming the additivity of fluidities, and using weight-fraction data in the calculations. The accuracy decreased the greater the difference in the viscosities of the components. Approximately the same degree of accuracy was achieved by using ASTM Chart D (D341-37T) as a blending chart.

The predictability of kinematic viscosity index, assuming it to be a linear function of the mole-, weight-, or volume-fraction, was not satisfactory.

The density of a mixture of pure heavy hydrocarbons was best estimated from weight-fraction data as a linear function.

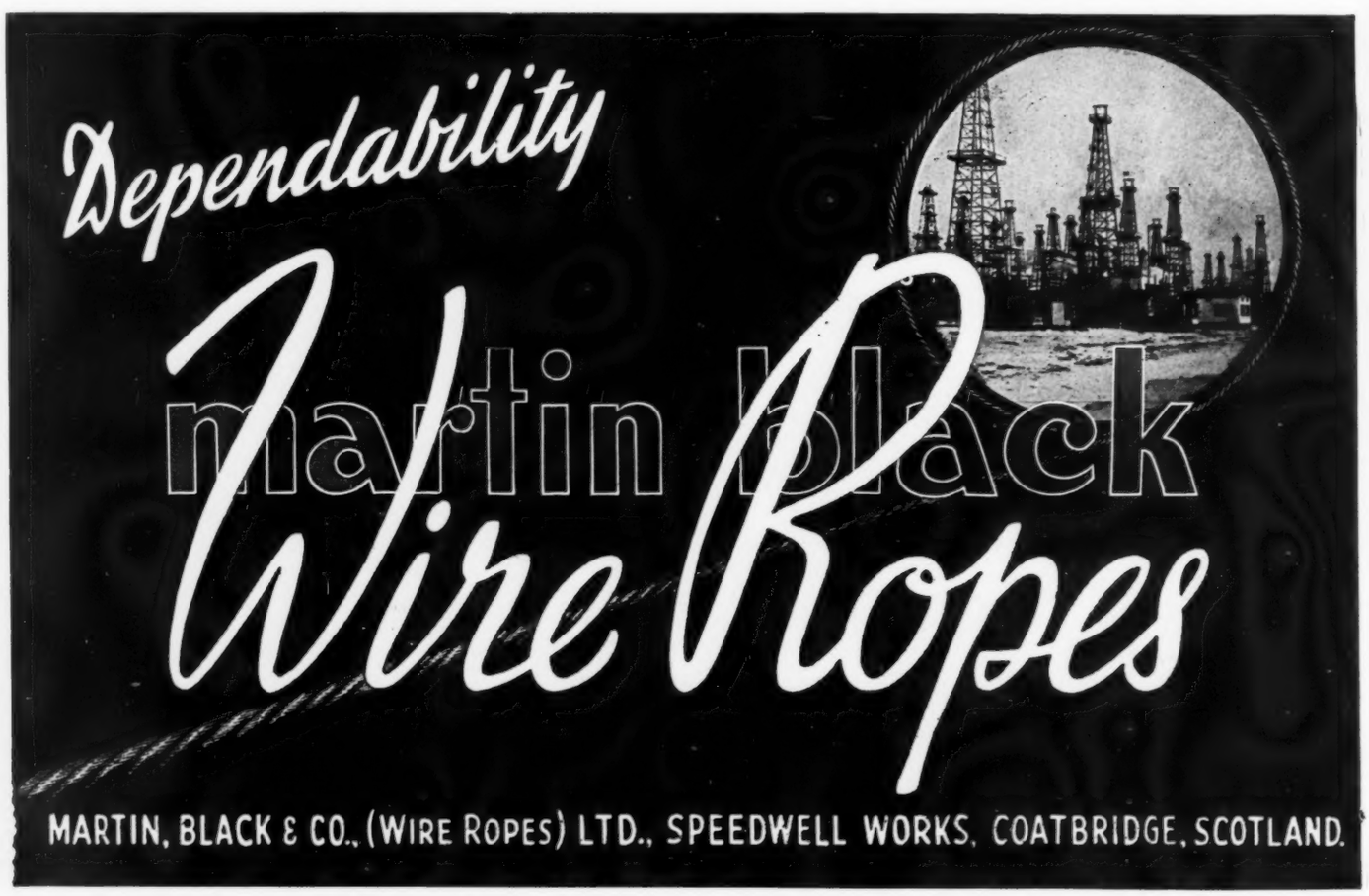
Volume-fraction data gave the most accurate values for the refractive indexes of these mixtures.

The aniline points of two of the complex mixtures were best calculated assuming the aniline points of the pure components to be linear functions of the weight, or volume-fractions.

Reproducible cloud and pour point data were obtained for the complex mixtures.

Utilization of Existing Vocational Training Facilities for Wartime Conditions in the Oil Industry—J. R. D. Eddy, before DIVISION OF PRODUCTION, AMERICAN PETROLEUM INSTITUTE, Houston Meeting, April, 1943.

The manpower problem in forcing all businesses



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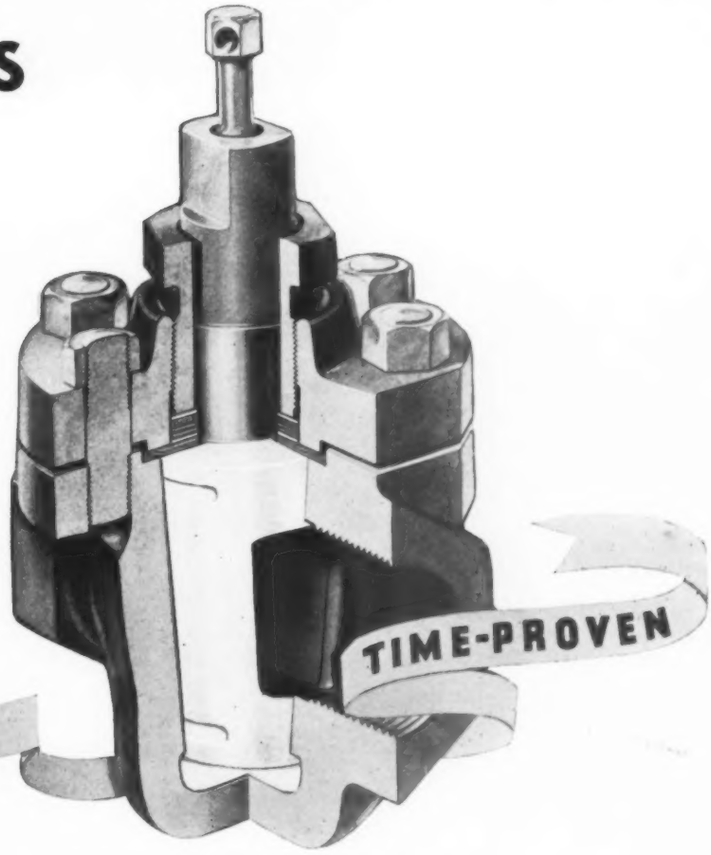

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CANADA: Peacock Bros. Ltd., Montreal, Quebec

KEEP UPKEEP DOWN WITH AUDCO-NORDSTROM VALVES

and industries to use large percentages of green, unskilled or semi-trained employees and creates the necessity for training programs to provide, first, trained supervisory personnel, and secondly, trained workers.

The author reports on how this need is being met by the vocational training division of the Texas State Board of Education. During the past ten years 16,518 oil field employees have been enrolled in 960 classes, classified as follows:

DISTRIBUTION OF ENROLLMENT

Title—	Number Enrolled 1933-38	1938-43	Total
Applied Math. (Elementary)...	5,049	1,280	6,339
Applied Math. (Advanced).....	476	555	1,031
Elementary Science	1,791	473	2,264
Internal Combustion Engines...	1,066	378	1,444
Steam Power	118	36	154
Compressors	....	....	....
Electric Power	115	158	273
Blueprint Reading and Sketching	385	1,120	1,505
Motor Vehicle Driving.....	....	....	....
Maintenance and Repair of Mechanical Equipment	248	217	465
Drilling Practices	36	77	113
Production Practices	83	909	992
Natural Gas Production	762	251	1,013
Manufacture of Natural Gasoline	172	606	778
Miscellaneous Courses (Not approved by Topical Committee on Vocational Training).....	....	....	149
			16,518

A second phase of this training program, which is of equal importance, is that of training foremen or supervisory personnel. During the past 10 years, foreman training conferences have been conducted for almost a thousand foremen. During the past 5 years, emphasis has been placed on the training of foreman trainers for companies. This is in recognition of the fact that foreman training should be a continuous program, and the best results can be obtained by training carefully selected leaders to act as foreman trainers within each company.

As a further aid in solving personnel problems accentuated by the present emergency, it has been arranged to supply highly trained foremen conference leaders who will be loaned to oil companies that want to train ten or more foremen; smaller companies may send men to classes at the Texas A. and M. College. Emphasis is laid on approved courses for upgrading employed personnel, including a part-time trade preparatory program for qualifying selected workers for particular jobs rather than consuming time for making them all-round workers, all with the idea of making green men available for employment at the earliest possible moment.

War-Time Protection of Petroleum Facilities—Kraus Earhart and M. J. Jolly, before DIVISION OF PRODUCTION, AMERICAN PETROLEUM INSTITUTE, Houston Meeting, April, 1943.

"Mechanized war means oil war" in the sense that airplanes, tanks, mobile artillery, ships and trucks that bring supplies to the front lines cannot move without oil and gasoline. Anything that impairs, even to a small degree, the ability of the American petroleum industry to provide these indispensible sinews of war, is of direct assistance to the enemy. Therefore, a first duty of this industry is to safeguard its facilities, and to take all necessary and available measures to avoid incidents that tend to reduce production.

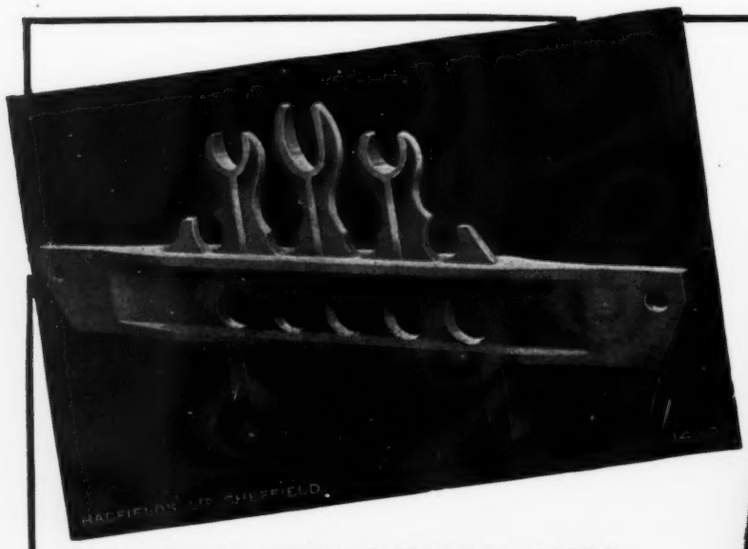
There is a good deal of justified worry about sabotage; it is a distinct credit to the vigilance of the military and the F.B.I. that there has been only a limited amount of real sabotage in this war. Much more costly is the unintentional sabotage of our own citizens who obstruct the war effort by neglecting to practice fire prevention and other precautions to eliminate waste and destruction of men and materials. Every fire that destroys even a single item of material or machinery, and every accident that keeps a skilled worker away from his job is to that extent a handicap on our fighters.

Fire and accident prevention is on the program of every petroleum company, and the situation is now such that these efforts must be intensified. Chief among the means to this end is to arouse the interest of the plant personnel. It is a mistake to assume, as is sometimes done, that employees are not interested. They are interested, and will respond when they are given to understand the need of safety and are instructed in the method of safety. Managers must accept responsibility for building the necessary morale and fostering special alertness in their people, otherwise it is they who are chargeable with preventable sabotage.

BOOK

Petroleum Testing Apparatus—Issued 1942 by Precision Scientific Company, Chicago; 96 pages.

Although a trade publication, this book (8½" x 11") is of interest as a comprehensive catalog of laboratory apparatus for all standard methods of testing petroleum materials and products, including those of the A.S.T.M., the Federal Specification Board, British Petroleum Institute, American Association of Highway Officials and other governing bodies; it is comprehensively indexed.



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